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THE COVER: The metallurgical microscope has proved to be a very valuable research tool for a number of investigations being conducted at the Laboratories. The cover illustration shows E. S. Greiner of the Metallurgical Research Department using one of these microscopes for a study of dislocations in germanium.

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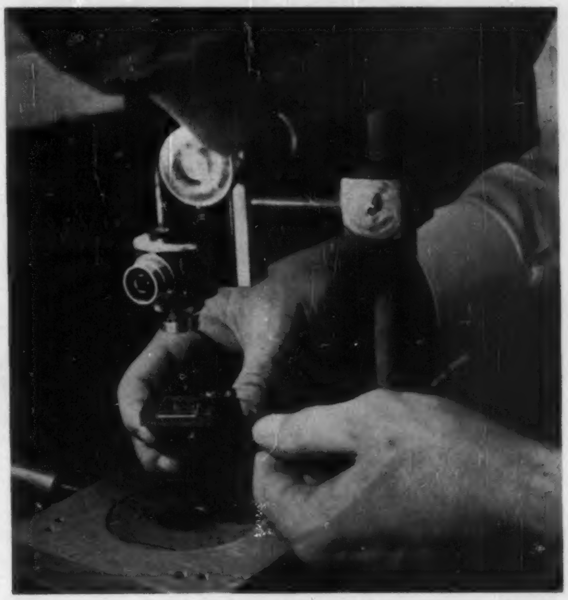
The Depth of Diffused Layers



W. L. BOND *Physical Research*

The diffusion of conductivity layers into semiconductor crystals has proved to be a major technological break-through in the fabrication of transistors and transistor-like devices. Because we deal here with minute amounts of material and extremely small dimensions, however, very precise methods of measurement were required. A technique of using interference fringe patterns has been devised to measure the depth of some of the thinnest of diffused layers within about one millionth of an inch.

Transistors and other semiconducting devices have rapidly become very useful components in modern electronic circuits, and they become more useful the more accurately we can specify their properties. The final specifications of such devices are chiefly electrical – resistivity, rectification ratio, frequency range and the like – but many of these trace back ultimately to certain physical dimensions of the semiconductor material itself or of the other parts associated with it in the completed structure. It is a consideration of some importance that since semiconductor devices are by their nature small in physical size, and since for some applications they tend to get smaller and smaller, we are challenged to refine our measurement techniques when we work with their minute dimensions.

The depths of different conductivity layers produced by the diffusion technique is a case in point. It has been found recently at the Laboratories[1] that by diffusing an element from the gaseous state into the surface of a crystal of semiconductor, it is possible to achieve certain properties that were difficult or impossible to obtain by the previous "crystal growing" or alloying methods. In this way we can get the large areas necessary for the high-power rectifiers[2] or for the Bell Solar Battery.[3] Also, the diffusion technique permits the fabrication of the thin layers that are necessary for very high-frequency semiconductor devices.

In a general way, the thinner the conductivity layers are in a transistor, the higher the frequency at which it will operate. As the layers get thinner, however, control and reproducibility become increasingly troublesome problems. Some experimental units are now being constructed with diffused layers as thin as 0.001 mm, and a slight departure from this thickness will have a decided effect on performance. It is therefore very important to measure this depth accurately so that it can later be related to the observed electrical properties.

At one time an attempt was made to determine the depth of the diffused layer by a procedure illustrated in Figure 1(a). The semiconductor (here silicon) with its diffused layer was encased in a

[1] RECORD, *February,* 1956, *page* 76. [2] RECORD, *August,* 1955, *page* 303. [3] RECORD, *July,* 1955, *page* 241.

block of plastic, and a surface perpendicular to the boundary was ground flat. The surface was then treated with an etching solution which attacked the diffused layer more than the body of the silicon. With this method, however, the resulting depression in the diffused layer was often less than 0.001 mm in depth and was difficult to detect.

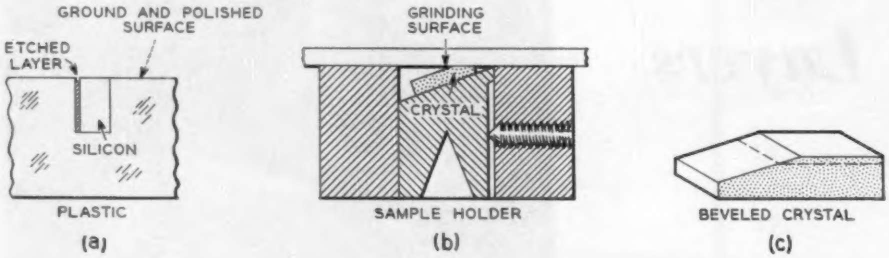


Fig. 1 — (a) Etching of diffused layer on surface perpendicular to the junction; (b) crystal in holder for grinding beveled surface; (c) crystal with beveled surface.

The other methods described here depend upon the use of a beveled surface, rather than the perpendicular surface seen in Figure 1(a). That is, the surface is ground at a shallow angle (usually about 5°) to the original surface of the material, as in Figure 1(b). The result is a structure like that seen in Figure 1(c), where the diffused layer is in effect greatly magnified by the bevel.

The lines delineating the diffused layer in Figure 1(c) are somewhat misleading because the junction between the layer and the body of the crystal is actually invisible. The opposite-conductivity type silicon or germanium in the layer looks exactly like the parent material. The position of the junction must therefore be identified before the depth of diffusion can be measured.

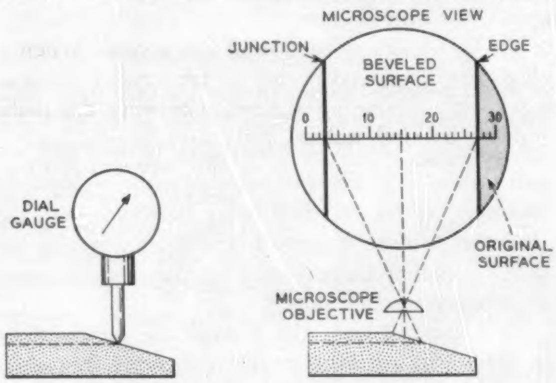


Fig. 2 — Left: the dial gauge method of determining depth of diffused layer; right: the microscope method for determining this depth.

There are several methods by which the junction can be identified and made visible. A positive-conductivity region in silicon, either a surface layer or the body of the crystal, can be stained with a nitric acid–hydroflouric acid solution. Germanium cannot be stained in this manner, but positive type germanium can be electroplated with copper. Since the copper is not deposited on the negative-type layer, the junction line is made visible.

The boundary may also be found by electrical test. A probe is run along the beveled surface until a decided change in current occurs at the junction. Or, since a hot metal point resting on a semiconductor acts as one lead of a thermocouple, a heated probe can be passed across the beveled surface, and the point where the current changes direction is the position of the junction. A scratch or line can then be scribed on the crystal so that the junction position can be seen in the subsequent optical measurements that are made.

Once the junction position is determined, there are again a number of techniques for determining the actual depth of the layer. Two of these are illustrated in Figure 2. The beveled crystal may be passed under a dial gauge which has a movable plunger that retracts as the crystal gets thicker. The depth of the layer is thus the difference between the dial readings when the point of the plunger is on the junction and when it reaches the top surface of the crystal. The beveled distance through the layer may also be observed through a microscope, and a value read from an eyepiece scale. The value on the eyepiece scale is related to the beveled distance, which is in turn related to the depth of the layer and the angle of the bevel.

Like the drawings in Figure 1, the representations in Figure 2 could be somewhat misleading, for the depths of the layers are here greatly exaggerated. In addition, the edge on the top of the bevel tends to be rounded off despite the most careful grinding procedure, and the junction line is often not clearly defined. Thus, with both the dial gauge method and the optical microscope method, there is usually a question where to spot the two measuring points – the apex edge of the bevel and the junction. The accuracy of the microscope meas-

urement also depends partly upon how exactly the angle of bevel is known, and upon the measurements of distances involved in the trigonometry of the microscope arrangement. Because of the cumulative effect of these errors, it is difficult in most cases to achieve an accuracy of much better than 10 per cent.

In an attempt to improve the accuracy of measurement, another method of depth determination has been devised. The principle involved is the familiar one of setting up an interference pattern in the manner of Newtonian rings. We perhaps remember the experiment of placing a slightly spherical-shaped piece of glass on a plane glass surface and allowing monochromatic light to shine upon it. At one point the two pieces of glass touch, but because of the spherical shape of one of the pieces, there is a gradually increasing separation as we go away from the point of contact. Light passing through the two pieces of glass encounters multiple reflections from the surfaces; in some places, reflected light is in phase with others of the reflections, but in other places the reflections are out of phase and are thus annulled. The result is a series of rings around the point of contact. Light areas show where the reflections are in phase, and dark areas show where the reflections are cancelled. The interference-measurement device that is described in the following paragraphs is based on a refined treatment of this same phenomenon.

Fig. 4 — Crystal in center of sample holder after hand polishing operation.

Figure 3 illustrates the principle of the instrument. The interference pattern is possible because of the bevel in one section of the crystal. When a glass plate is placed on top of the crystal, there is a gradually increasing separation between this plate and the beveled surface, just as we have a gradually increasing separation in the Newtonian rings experiment. Light passing through the plate and striking the crystal can reflect from the two adjacent surfaces to give two wave trains that interfere with one another and thus cause the interference pattern.

At the left in the illustration, sodium light of nearly constant wavelength (about 5,900 Angstroms) is directed to a "half-silver" mirror which permits part of the light to be reflected toward the crystal and part to pass through. After multiple reflections in the crystal-plate assembly, light returns through the half-silvered mirror toward the eyepiece, where it either reinforces or interferes with the light reflected directly from the sodium lamp. The eye therefore sees an interference pattern, which is used to determine the depth of the diffused layer. The number of interference lines is in fact a direct measure of depth.

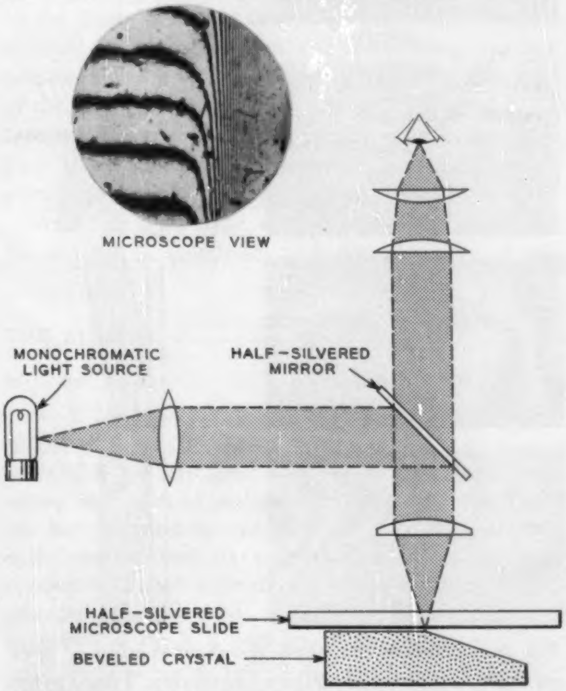


Fig. 3 — Interferometer adapted for measurement of depth of diffused layers.

The refinements in this procedure are chiefly in the method of establishing the interference pattern, and in the manner of mounting and adjusting the

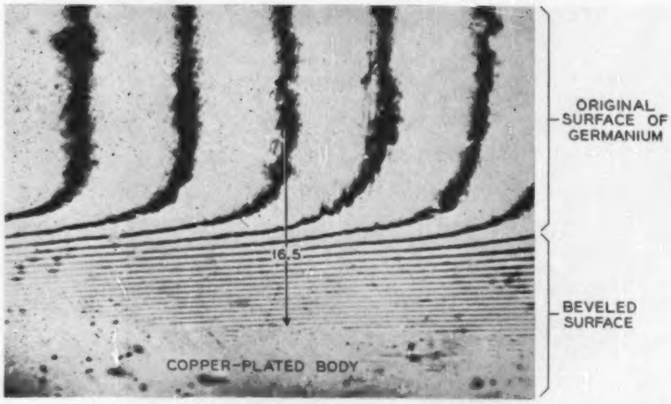


Fig. 5 — Interference pattern from germanium with a diffused layer (magnification 5,900 diameters): lines at top of photograph are from the original surface of the crystal; closely spaced lines in middle result from the beveled surface of the layer; area without lines at the bottom is the copper-plated body of the crystal.

sample to produce an easily usable orientation of interference lines. The plate placed on top of the crystal, like the main reflecting mirror, is a half-silvered piece of glass (actually a piece of ordinary microscope slide is sufficiently flat over the microscopic areas used). The silvering increases the multiple reflections, which in turn increases the sharpness of the lines. It also improves the resolution of the lines; that is, the dark areas are narrower and more sharply defined than in the usual Newtonian rings arrangement. This permits the accurate identification and counting of lines necessary for the depth determination.

The second refinement – that of mounting and adjusting the position of the sample – can be explained with reference to Figure 5. This is a microscope photograph of an actual interference pattern of a beveled piece of germanium which has a positive-type diffused layer about 0.005 mm thick. The value of adjusting the position of the sample arises from the difficulty that the top edge of the bevel is always slightly rounded and therefore ordinarily difficult to identify. However, if we orient the sample assembly so that the lines resulting from the original surface of the crystal are perpendicular to the bevel, the roundness of the bevel edge does not enter into the measurement.

As seen in Figure 5, the widely spaced lines curve into the closely spaced region. This is an indication of the roundness of the bevel edge. If the edge were perfect, the intersections would all be sharp angles. Here, however, the roundness of the edge makes no difference. Since the widely spaced lines are perpendicular to the bevel, a count of the number of lines to the junction will always be the same, provided the junction is sharply delineated. For example, in Figure 5 a line has been drawn tangent to one of the widely spaced vertical lines, and a count of 16.5 lines has been determined to the junction. Within limits, this count is constant regardless of how much the bevel edge has been rounded in the grinding process. At 5,900 Angstroms, the distance between any two lines is 0.00295 mm, so 16.5 lines reveals a junction depth of 0.00485 mm.

A procedure for getting the desired orientation of lines and for displaying the junction line accurately is illustrated in Figure 6. The topmost of these four microscope photographs shows a portion of a germanium crystal on which two strips of aqua dag (suspended graphite) have been painted. Between these two strips, a probe was dragged down across the bevel edge to the position of the junction. When the junction was reached, the probe was then passed over the aqua dag in the horizontal direction, so

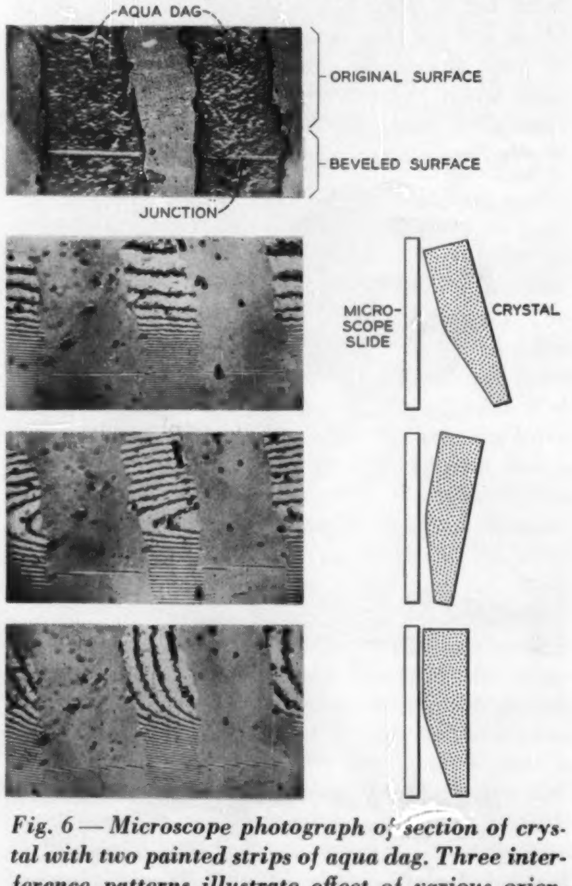


Fig. 6 — Microscope photograph of section of crystal with two painted strips of aqua dag. Three interference patterns illustrate effect of various orientations of crystal and half-silvered microscope slide.

that the probe scratched a line through the graphite. This scratch is visible in the three interference-pattern photographs. The aqua dag is readily wiped off later and hence gives a nondestructive test. Scratching the germanium itself would be destructive.

To the right of each of the three interference photographs is shown a representation of the position of the crystal in relation to the half-silvered microscope slide. In the first of the three, the rounded bevel edge is farther away from the slide than is the rest of the original surface. This results in a pattern in which the widely spaced lines are parallel to the closely spaced lines. Next, the rounded edge is closest to the microscope slide, which results in the different pattern seen in the photograph. Finally, as seen in the lowest part of the illustration, the original surface of the crystal is (in cross section) essentially parallel to the slide, and we have the desired pattern. In theory, of course, if the original surface of the crystal and the surface of the microscope slide were both perfect planes and were both absolutely clean, no lines would result from the original surface of the crystal. Actually, however, there is always a little dust or other foreign matter which keeps the two surfaces slightly separated and slightly out of parallel. The crystal and the slide are therefore adjusted to be slightly out of parallel around a vertical axis parallel to the page in Figure 6, so that the widely spaced vertical interference lines are established on the original surface. These adjustments of the positions of the slide and crystal are made on a special sample holder. Screw adjustments apply slight pressures that force the crystal and slide into the correct orientation.

With this technique, only a very small portion of the crystal is examined, and non-planarity of the

Fig. 7 — E. Berry placing crystal holder in polishing machine prior to beveling operation.

crystal surface or of the surface of the microscope slide therefore does not greatly affect the accuracy. Also, provided the closely spaced lines are clearly differentiated, neither the angle of bevel nor the planarity of the beveled surface enters into the calculation. The only sources of error are the accuracy of the position of the junction line, the accuracy with which the frequency of the monochromatic light is known, and the accuracy of the manual operation of positioning and counting the junction lines. With the precise method of scratching the junction line into the aqua dag, accuracies of 0.00003 mm are possible. A layer only 0.001 mm in depth can be measured within 3 per cent. Such good performance should permit a more exact control over the diffusion process, and should permit the fabrication of semiconductor devices with more precisely specified properties.

THE AUTHOR

W. L. Bond entered the Laboratories in the fall of 1928, after receiving the degree of B.S. in Physics in 1927 and the M.S. degree in 1928 from Washington State College. In studies of the piezo-electric effect in minerals, he surveyed the entire mineral field and made similar investigations of many synthetic crystals. He has designed optical, X-ray and mechanical tools and instruments for the orientation, cutting, and processing of crystals. Mr. Bond also served as consultant on quartz crystals with the War Production Board. More recently Mr. Bond has engaged in studies of dislocations in semiconductors by means of infra-red microscopy. He is a member of the American Physical Society, the American Crystallographic Association, and is Chairman of the International Commission on Nomenclature of the International Union of Crystallography.

Switchboards for Telephone Answering Services

G. D. STEWART *Switching Engineering*

Switchboards used by private firms in supplying telephone answering and secretarial service to their clients have special features to meet the needs of these services. The features include privacy for calls answered by the client, and prevention of calls being originated by the answering bureau. Until recently, a variety of switchboard arrangements were provided by the Operating Companies for telephone answering-services. Now, two new switchboards have been developed specifically for this purpose.

Since the installation of the first Secretarial Answering Bureau in 1920, telephone answering-service firms have mushroomed to where today about 1,500 bureaus serve nearly a quarter million clients. Answering-service lines are still increasing by about 30,000 a year. To meet this vast growth, the Laboratories recently developed two new switchboards to help the Operating Telephone Companies meet their customers' needs.

Telephone answering service is a service offered by private firms whereby many businesses and professional men with offices that are manned only part of the time may contract with an answering bureau to have their incoming calls answered during such periods and in such manner as they may desire. Attendants at these bureaus take messages, make appointments, and in other ways perform duties similar to their clients' representatives or secretaries. In order that the answering bureau may answer incoming calls, it is necessary for a client of the bureau to arrange with the Telephone Company to extend his line from the central office to the bureau, where the line appears at a jack plus a supervisory lamp on a switchboard. The Telephone Company receives rental from the answering bureau for the switchboard and receives additional rental from the customer for the telephone plant involved in extending his line to the bureau. Privacy on outgoing calls by the client is assured by the design of the new, special-purpose switchboards.

Studies indicated that the requirements for this service could best be met by the development of two new switchboards for answering-bureau use – one for those areas where combined PBX and answering-service operation is permissible and another for areas where interested commissions and regulatory bodies do not permit this combination. The two new switchboards developed by the Laboratories for this use are the 557A and 557B.

Each of these boards is a manual, single-position, self-contained switchboard with large designation strips upon which the client's name, address, telephone number and contracted class of service may be typed, a large writing shelf covered with a plas-

tic bulletin holder and exterior wood panels that are readily removable for refinishing and maintenance. The 557A offers combined secretarial and PBX service using conventional self-contained double-cord units now in use in the 555 PBX,* while the 557B is for answering-service only and employs single-ended answering cords of a new design.

Concentrator-identifier (CI) equipment has been developed for use where the answering-service bureau is located some distance from the central office. This is a means of concentrating up to 100 clients' lines in a central office, routing incoming calls on these lines over four pairs of cable wires and identifying the lines at the answering bureau on a switchboard. Both the 557A and 557B boards were developed so that they included the use of the new concentrator-identifier features.

While both boards are 2½ feet wide and 2½ feet deep, with a writing shelf 30 inches above the floor, the 557A is somewhat taller – approximately 5 feet high. The upper portion of the jack panel of the 557A is arranged for 5 answering-service line units across its width. Each unit contains jacks, lamps, relays, gas tubes, and designation strips for 20 answering-service lines. Space is available for a maximum of 100 lines. Jacks may be provided in the lower portion of the panel for central office trunks, tie trunks, conference circuits, and administrative stations, together with their associated lamps and designation strips in groups of 10. Designation cards for the answering-service lines are mounted in individual holders above the lamp caps

* RECORD, *April*, 1949, *page* 125.

Fig. 1 — Miss Isabella Waegelein operates a 557A switchboard in an answering bureau in Chicago.

for the various lines, while a common strip-type designation card suffices for trunks and other lines.

Fifteen cord units can be mounted across the lower part of the board, each one comprising two cords, two lamps, two keys and associated relays. Conventional cord weights are used. A pilot lamp installed in the lower part of each half of the board provides an indication when at least one answering-service line is calling in that half of the board. An-

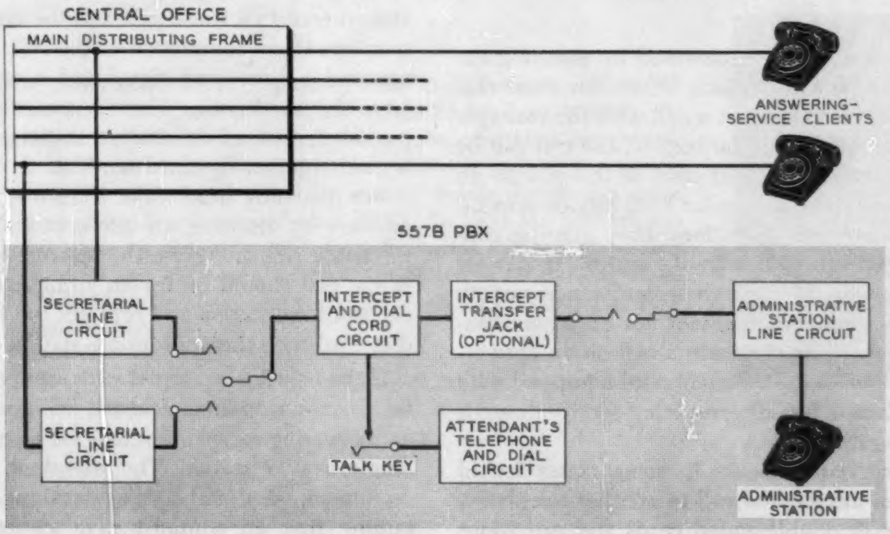


Fig. 2 — Answering-service facilities of the 557B.

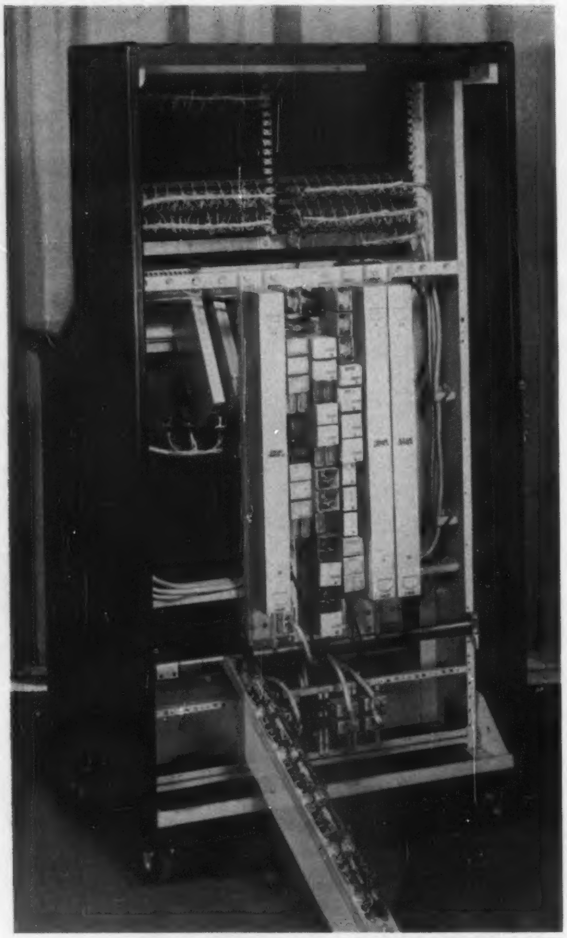


Fig. 3 — Rear of 557B switchboard showing one cord unit lowered for maintenance.

swering-service lines are answered by inserting the left cord of a pair in the jack. When, for some reason, it is desired to connect a call with the manager or some other person in the bureau, the call can be extended through the right cord of the pair to an administrative station. Regular PBX service is available for administrative stations; they may be connected with central-office trunks and tie trunks, or together directly or through a conference circuit. However, neither the attendant nor an administrative station user can originate a call on an answering-service line. A 557A switchboard equipped with jacks and lamps for 20 answering-service lines is shown in Figure 1.

Regulatory requirements in some states forbid extending an intercepted call to another telephone, so boards with double-ended cords and provisions for regular PBX service may not be used.

The 557B switchboard, shown in the headpiece, was developed for use where combined secretarial and regular PBX service is not permitted. It incorporates new apparatus and mounting techniques that permit a height of only 4¼ feet, similar to that of the 551-type boards now used for answering service by most Operating Companies. Either a standard 10-pulse dial or an operator's 20-pulse dial may be mounted at the right of the cords. Jacks mount in 10-jack strips on either side of the center.

On answering-service lines, the designation strip covers the lamp sockets and allows the lamps to shine through holes in the strip, eliminating the need for lamp caps. Ten individual plastic windows to cover the designation cards may be installed on each strip. These windows and cards may be readily removed by the attendant to change designation information. All other lines in the board use standard 10-jack designation strips and cards.

A maximum of 100 answering-service lines may be installed, but only 5 central-office trunks are provided. Up to 8 intercept-and-dial cord units may be supplied. Figure 2 shows how the lines are answered. A single cord and key is used to answer each incoming call but, because the cord units are connected in series, it is not possible to patch two intercepted calls together. A maximum of 3 administrative stations may be connected to each 557B position, relay equipment for three station cords being furnished with the switchboard.

Should an administrative station originate a call, the lamp in its station cord unit lights and the attendant answers by operating the talking key associated with the lamp. She then inserts the associated station cord in a trunk jack and the station dials the number. Upon completion of the call, the attendant receives a disconnect signal and removes the cord from the trunk jack. Where a conference circuit is provided, two administrative stations may be connected together by the attendant.

For incoming trunk calls, Figure 4, the attendant answers by inserting an intercept-and-dial cord in the trunk jack and gives the information requested. If the call should be for an administrative station, she rings the station and replaces the intercept-and-dial cord with the appropriate station cord.

If the board is equipped with intercept-and-transfer jacks, an optional feature, an incoming call on an answering-service line may be transferred to an administrative station. The attendant answers with an intercept-and-dial cord as usual and, upon ascertaining that an administrative station is desired, rings the station and plugs the station cord into the

transfer jack associated with the intercept cord used. The equipment has been so designed that, upon completion of the call, it is impossible for the administrative station or the attendant to originate a call on the intercepted answering-service line.

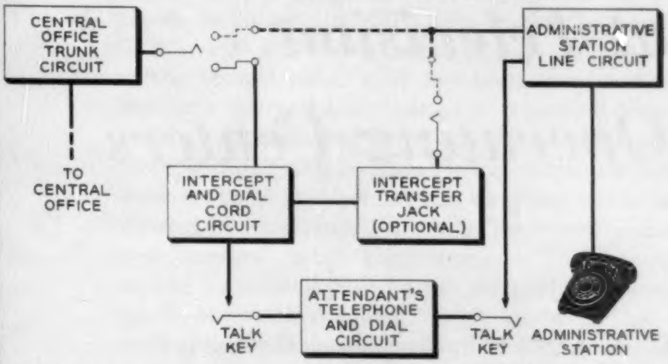


Fig. 4 — Arrangements of 557B switchboard for trunk calls.

Lamps for answering-service lines may be so arranged that the attendant must answer the line to extinguish the lamp. A pilot lamp installed in each half of the board below the jack field provides an indication when at least one line or trunk lamp is lighted in that half of the board.

Both Concentrator-Identifier lines and regular answering-service lines can be used on the same board. A simplified line circuit unit is available for terminating each 10 lines served by a concentrator-identifier. In certain instances where CI lines are used, the number of line lamps displayed may exceed the number of available CI trunks; a "no cut-through" tone may be provided to indicate this condition to the attendant.

Cord units in the 557B utilize a new three-conductor cord ⅜-inch in diameter, and cord reels instead of cord weights. These self-contained units mount in the switchboard with two screws, and are equipped with a jack and plug for connecting them together and to the attendant's telephone circuit equipment. The combined intercept-and-dial cord unit has a 2-position normal and talk-dial key while the station cord unit has a 3-position talk-ring key with a normal off position. The cord units do not include any relays but utilize two relays in the attendant's telephone equipment. Relay equipment for all but answering-service lines is mounted on a common unit in the rear of the board. The common unit and all answering-service line units are on vertical mounting plates, hinged at the base so that they can be lowered for easy maintenance, Figure 3. All units and the line cables may be readily installed or removed through the use of jacks and plugs. Additional equipment, required for various optional features, mounts in the space below the writing shelf in back of the front panel.

The introduction of these two boards permits the Operating Companies to offer standardized switchboards to answering-service companies, with features designed especially for such service.

THE AUTHOR

G. D. Stewart received his I.E.E. degree from the Pratt Institute, and joined the New York Telephone Company in 1921. Since then he has been actively engaged in designing such circuits as commercial service observing equipment, special wiring plans, key pulsing equipment for long distance calls at pay station switchboards, and is the designer of a tool for making Braille designation strips used to enable blind attendants to operate some PBX's. In 1953 Mr. Stewart was loaned to the Laboratories to design the 557B PBX. Following this he collaborated on equipment layout for the 756A crossbar PBX. On March 1, 1956, he returned to the New York Telephone Company and currently heads a group handling PBX equipment and special circuits.

Switching Control at Television Operating Centers

C. A. COLLINS *Transmission Engineering I*
L. H. HOFMANN *Special Systems Development*

The problem of coordinating television programs from black-and-white studios, color studios and remote pickups is handled by the master control room of the TV station concerned. When the station is part of a nationwide TV network, however, program material from all over the country must be similarly coordinated so that the station can broadcast programs originating in other cities. This is the job of the Bell System television operating centers in many different cities, where TV programs handled by various Bell System facilities are switched with split-second timing.

When a television program ends, the face of the weather man in your city might be replaced by an advertisement or a scene televised from Hollywood, New York, Chicago, or practically any place in the country. You may realize, vaguely, that some sort of electronic equipment has performed this feat, but you probably are not aware of the Bell System resources that are involved. The Bell System supplies not only the intra-city and transcontinental facilities for such telecasts, but it also supplies the switching facilities that make it possible to change programs so rapidly.

Switching of television programs involves two separate areas: sound, and video or picture. At the present time, nearly all switching of TV sound is done at and by the station or network. TV sound is transmitted over various Bell System program facilities previously built-up for the networks primarily for radio purposes, and a great deal of the switching takes place at the broadcaster's studio between available sound facilities. On the other hand, the more costly video facilities are used in various combinations as the needs of the broadcasters vary from hour-to-hour, and switching is done at Bell System television operating centers, known as TOC's.

Within a TOC, there are also two separate areas: the actual switching of incoming and outgoing video lines, and the control equipment that permits such switching to be done at the proper times. A new video switch has been developed by the Laboratories to take care of the actual switching within the transmission limits imposed by network color TV, but a special control circuit was required to permit optimum use of the new switch by Bell System operating personnel with minimum fatigue and possibility of error.

Previously, the video switching control panel at a TOC consisted of a matrix of push buttons over which colored sleeves were placed to indicate the conditions of the various switches. The actual video switches were behind the panel, operated directly by the push buttons. The new video switch consists of resistance pads and wire-springs relays, and may be located away from the control panel. Since the new control panel is designed to operate switching relays, it can also be used to control switches in

TD-2 microwave radio relay stations and in coaxial cable terminals. Furthermore, it is anticipated that in the reasonably near future TV sound and video may be switched simultaneously at TOC's, and this is provided for in the new design. Two sizes of control panel are available, providing control for 20 inputs to 20 outputs (20 x 20) or, for the larger TOC's, a 30 x 30 arrangement.

The control panel itself has been simplified so that little instruction is required in its method of operation. All incoming lines appear on horizontal rows, and outgoing lines on vertical columns. Each intersection of an incoming and outgoing line is indicated by two lamps – a white "pre-select" and a red "execute" lamp. Each incoming line is controlled by a black push button alongside its nameplate, and each outgoing line is controlled by a white push button near the bottom of each vertical column. Below the white push buttons, a group of amber push buttons and lamps permit nearly simultaneous or "salvo" operation of several switches at one time. At the very bottom of the control panel are green "annul" buttons for use when an error in selection must be erased.

To prevent the possibility of an accidental switch of a television program by an attendant pressing the wrong button or something accidentally touching one of the buttons, the control panel is arranged so that no single button causes anything to happen; two buttons must be pressed simultaneously. For example, if an incoming and outgoing line are to be connected at some specified time or when a "cue" is received, the operator must press both the correct white and black buttons to "pre-select" the switch. A pre-selected switch is indicated by the lighting of the white lamp at the intersection of the two

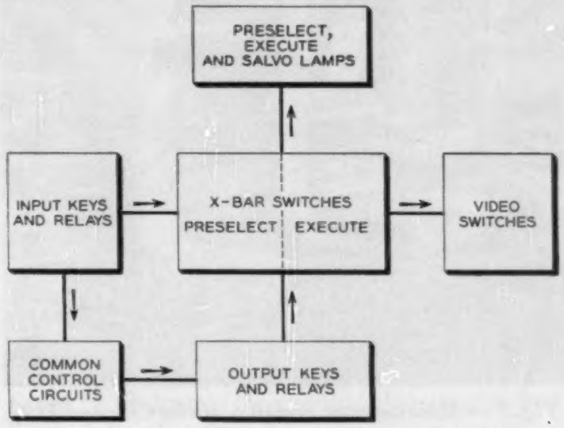


Fig. 2 — Block diagram of switching control equipment in a television operating center.

desired lines. Later, when the switch is to be made, the white button and either of two (three in a 30 x 30 arrangement) red "execute" or master buttons must be pressed simultaneously. When this is done, the white lamp goes out; when the buttons are released, the associated red lamp lights to indi-

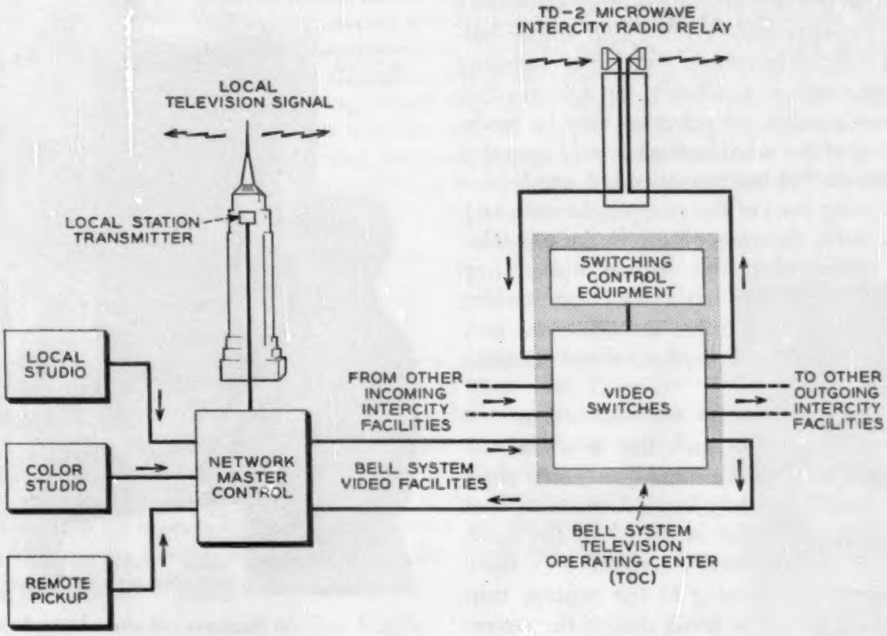


Fig. 1 — How a TOC controls all types of incoming and outgoing video facilities.

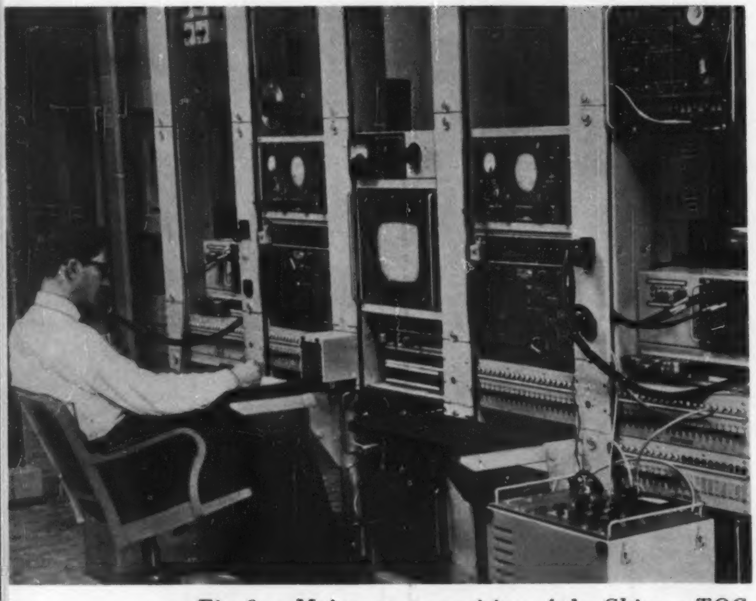


Fig. 3 — Maintenance position of the Chicago TOC.

cate that the switch has been made and that the outgoing line is in service.

Each time a pre-selection is made and a white lamp lights, a corresponding amber lamp also lights in the top row of amber "salvo" lamps. This indicates that all pre-selections can be executed at one time by pressing the top amber salvo button and the red execute button. Moreover, any preselected switches can be put into any of the other salvo rows by pressing the appropriate white and amber buttons. If it is desired to switch a group of outgoing lines simultaneously at a different time from other outgoing lines, a salvo pre-selection may be made. To do this, one of the salvo buttons is held operated and the white output buttons operated one-by-one for those outgoing lines of the group to be switched. When this is done, the amber lamp in the top salvo row will be extinguished and another amber lamp will be lighted in the new salvo row corresponding to the particular output. Salvo pre-selections may be changed by using the desired salvo and outgoing line buttons.

When, through error or for some other reason, a line pre-selection is made such that a white preselect lamp is lighted at the same coordinate point where a red lamp is already lighted, meaning that this outgoing line is to be switched to the same incoming line it was previously connected to, there will be a momentary opening in the existing connection. To prevent such a break during the course of a program, the undesired white lamp and its associated amber lamp in the salvo bank can be extinguished and the pre-selection nullified by operating the annul button and the white outgoing line button involved in the existing connection.

The lowest row representing incoming lines is set aside as a "no-service" line for test purposes. A feature of the design of the new video switch is that tests may be made on incoming lines without affecting transmission. To test outgoing lines, however, some means must be available to indicate when the line is free so that test signals will not interfere with regular programs. Pre-selection of an outgoing line for test purposes may be made in the same manner as for connecting it to an incoming line, except that the black button of the lowest row is pressed. This lights a white lamp in that row as usual. Upon execution, a green lamp lights in that row instead of a red one, indicating that the outgoing line is free and available for tests. An indicating lamp also lights at the maintenance center to tell the personnel there that the line is free. When a test is applied at the maintenance center, a third lamp, with a distinctive cap — white with a black circle on it — lights in the no-service row of the control panel, indicating that a test is in progress and that the outgoing line should not be preselected for regular use.

A special feature permits an interesting and highly useful delay in the execution of any switch. At times it is desirable to delay a switch for a few

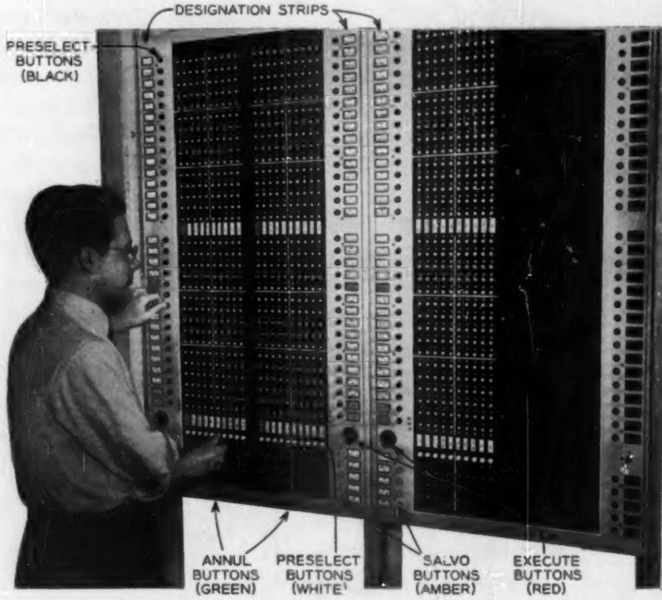


Fig. 4 — Two buttons on the control panel must be pushed simultaneously to initiate any action.

seconds until a cue is received, or perhaps to delay the closure of a "round-robin" circuit until it is broken somewhere else. At the designated time, the operator presses and holds the red button and whichever other button is appropriate. When the cue is received, release of either or both buttons makes the connection.

The physical equipment of the switching control circuit consists of the control panel proper, crossbar switches, and relays as indicated in Figure 2. The 20 x 20 size requires one standard equipment bay for mounting, while the 30 x 30 size requires four bays. Operated crossbar switches provide the memory for the preselections and salvos, and provide grounds to operate the video switches and light the panel lamps. All push buttons except the white buttons are duplicated on opposite sides of the panel. Two independent sets of common-control equipment are associated with the two groups of push buttons, permitting either set to be used in normal operation. Should one set of common-control equipment be inoperative because of a fuse failure or other trouble, switches could still be made using the other equipment.

Fusing the equipment required special consideration. Equipment for each outgoing line is therefore fused separately, so that one fuse blowing will not affect any of the other lines. To further safeguard the equipment in case of trouble, outgoing lines in groups of five and the two sets of common-control equipment are supplied by two power buses, each of which is individually fused. With such an arrangement, if one of the two distribution fuses should blow, half the lines would be inoperative. To avoid this, a resistance is bridged across each distribution fuse, capable of supplying holding current to the relays and crossbar switches, maintaining operation until the trouble can be corrected. The usual office alarms sound in case of trouble.

Although it is difficult to see how it might happen, the possibility of two incoming lines being connected to any outgoing line has been prevented by the design of the control circuit. If two black buttons should be depressed at the same time as a white button, no pre-selection would occur and it would be obvious to the operator that an error had been made.

In addition to the obvious requirements of adequate switching and switching-control of programs, each TOC includes one or more monitor positions

THE AUTHORS

C. A. Collins received a B.S. in E.E. degree from the University of Washington in 1925, and joined the Pacific Telephone and Telegraph Company in that same year. He transferred to the Laboratories in 1930. For four years he was engaged in switching studies and equipment engineering for community dial and larger step-by-step central offices. Following this, Mr. Collins worked on equipment design for No. 1 crossbar, No. 4 toll crossbar and local control equipment for dial systems. During World War II he taught in the Laboratories School for War Training. Following the war, he worked on studies concerned with CAMA, line concentrator and electronic switching. For the past two years he has been engaged in switching and transmission engineering work on television operating centers.

L. H. Hofmann received his M.E. degree from Stevens Institute of Technology in 1932, and a M.S. degree in Electrical Engineering in 1940 from Columbia University. He joined the Laboratories in 1936 and was with the Personnel Department until 1941. During World War II, Mr. Hofmann worked on fire control equipment at the Frankford Arsenal, and taught the use and operation of the proximity fuse at the Applied Physics Laboratory of Johns Hopkins University. Following the war, he was engaged in studies on mercury contact relays and the design analysis of circuits for No. 5 crossbar. Later, he turned his attention to switching problems in the television operating center.

so that a visual and audible check can be made of programs being handled. Each monitor position is provided with its own output circuit from the video switch and therefore can be switched to any incoming line. Circuits for the monitor position are equalized to the input of the video switch, as are all other outputs, and thus have no deleterious effect on the video transmission characteristics.

Also part of a TOC is a maintenance position, where tests can be made on any part of the switch and monitoring equipment. All test equipment is rack-mounted, and patch cords have been replaced by key operations. Because of this arrangement, equalization of all equipment can be made to the input of the video switch and any piece of test equipment can therefore be connected to any line through an essentially distortionless circuit. In addition, each piece of test equipment is cabled to a patching jack field over trunks carefully cut to the same electrical length. Coaxial patch plugs can then be used in place of patch cords.

The new video switch, control equipment, monitoring and testing facilities for TOC's are part of an integrated plan for furnishing broadband video transmission facilities to telecasters. Anticipating future developments in color and closed-circuit TV, the video switch equipment except for certain amplifiers was engineered to handle signals up to 10 megacycles wide instead of the present-day 4 megacycles. Should future requirement make it necessary to accommodate 10 megacycles, new amplifiers may be added to make use of the full bandwidth. The safer, more flexible control of switching permits the future use of more complex switching arrangements in TOC's, and the new equipment is expected to be widely used as Bell System TV transmission facilities continue to expand with the television industry.

Telephone Service Begins Over New Alaskan Cable

The U. S. Army Signal Corps and the Bell Telephone System recently opened to public service a new and important communications link between the United States and the growing Territory of Alaska. The link consists of an underwater telephone cable system stretching some 1,250 miles from Port Angeles, Wash., to Skagway, Alaska. The cable was designed by the Laboratories.

Hatfield Chilson, Assistant Secretary of Interior and D. Frank Heintzleman, Governor of Alaska, made the first call over the new system. Mr. Chilson spoke from Washington and Mr. Heintzleman from Juneau. The inaugural call was made over a 4,600-mile telephone network that linked Washington to Juneau and included Seattle, Ketchikan, Anchorage and Fairbanks. At each location, government, military and industry officials participated in the ceremonies.

The cable system represents two major projects: one provided by the Long Lines Department of A. T. & T., and the other by the Alaska Communications System which is operated by the Signal Corps.

The A. T. & T. cable system extends from Port Angeles to Ketchikan, Alaska, a distance of about 900 miles. Twin cables, containing built-in amplifiers, lie in the ocean depths off the coast between the two points. These cables were placed by the U. S. Army Cableship Albert J. Myer between early June and late August. They are similar in design and construction to the transatlantic telephone cable system – the first such system to cross an ocean – which went into service Sept. 25.

The Alaska Communications System cable, which covers the 400 miles between Ketchikan and Skagway, is a single submarine cable stretching along the inland waterway on the southern coast of Alaska. This cable utilizes amplifying stations that are located on islands or points of land in the area.

From Port Angeles, the southern terminal, the cable circuits are connected to the U. S. network at Seattle by a radio relay link recently constructed by the Pacific Telephone and Telegraph Company. At the northern end, beyond Skagway, the circuits are fed into the Alaska communications network, operated by the Alaska Communications System. The system took over two years to build. It can carry 36 conversations at one time and will be used to supplement the radio-telephone and land line facilities that have been operating between the United States and Alaska since 1937.

Dial Testing Equipment

F. WEST *Station Apparatus Development*

Many telephone users have a vague idea that somehow the operation of a telephone dial has something to do with the apparatus needed to route a call to the desired destination. Relatively few users realize, however, that the dial actually generates series of pulses that direct automatic central office equipment in completing a call. These pulses must be of the right size, shape and frequency so that the switching equipment will react properly. Recently, a new method has been developed at the Laboratories to test the performance of dials and assure that they will generate pulses accurately.

Telephone dials perform the important function of producing the pulse trains required to establish the interconnection of two telephones in a machine switched telephone system. These pulse trains are produced during the "run-down", after the finger-wheel is released, by means of a cam-driven pulsing contact which interrupts the current in the loop to the central office at a uniform rate. The number of pulses produced by these interruptions during the run-down is the same as the digit number that is being dialed.

The central office equipment that receives these dial pulses will perform correctly only if the pulses have specified characteristics. Hence, it is important that the dial be properly designed and constructed to provide such pulses. Particularly important are the make and break times of the pulsing contacts; these times must be accurately repeated pulse after pulse. The percentages of a pulse period that are devoted respectively to the open and closed states of the pulsing contact; that is, the "per cent break" and "per cent make" are determined by the cam that drives the contacts, and by the relative location of the contact springs and the cam. The total duration of a pulse is determined by the run-down speed of the dial which is controlled by a centrifugal governor. Hence, the time of break and time of make are determined by the per cent break, or make, and the dial speed. The nominal dial adjustment is for 61 per cent break and a 10 pulse per second speed, and at present, manufacturing tolerances of ± 3 per cent break and ± 0.5 pulse per second are set for these values.

Recently developed dials for use in the new telephone sets possess operational precision that make previously existing laboratory equipment inadequate for measuring their pulse characteristics. A study was, therefore, instituted to develop an improved measuring device. This study resulted in the machine illustrated in the headpiece of this article which displays the break and make time of every operation of the pulsing contact during dial run-

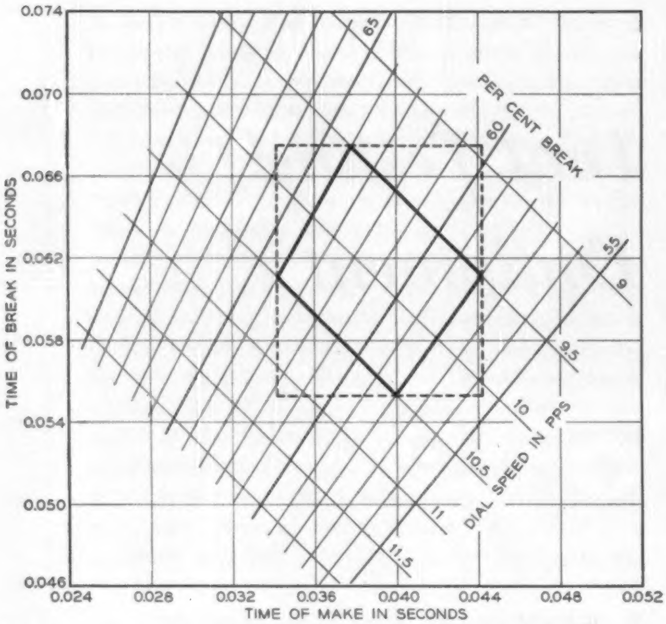


Fig. 1 — Graphic representation relating time-of-break and time-of-make to per cent break and dial speed.

down. The display appears on the face of a cathode ray tube in the form of dots plotted on the coordinate axes of Figure 1 with break time as the ordinate and make time as the abscissa. Each dot represents the break and make time of the contact operation of a single pulse.

Laboratory use of this equipment has demonstrated the expected merits of this method. Contact behavior for each pulse can be observed during the dial run-down, and the progress of the dot pattern aids in determining the cause of faulty dial operation, when present. Figure 1, which is a diagram relating time of break and time of make to per cent break and dial speed, shows that a dot progression along a line of constant per cent break on the scope would cross lines of constant speed. This would show that the dial speed was changing during run-down and throw suspicion on the governor. Similarly, a progression of dots along a line of constant speed would show variable per cent break, and point to trouble in the pulsing contact or associated mechanism. A widely scattered dot pattern would show a variable condition with some such possible cause as an eccentric or damaged gear in the dial gear train. Thus, in the same time as is required by previously used dial testing equipment, the new machine provides a considerably larger amount of more direct information about dial characteristics.

An additional value of the pictorial presentation of the dial performance can be explained by reference to Figure 1. In this diagram lines representing the established limits of maximum and minimum per cent break and speed form a diamond-shaped area which encloses all possible acceptable combinations of per cent break and speed. Horizontal lines through the upper and lower apices of the diamond, and vertical lines through the right and left apices, define the maximum and minimum break and make times which correspond to the limits established for speed and per cent break. These lines, shown dashed in Figure 1, enclose a rectangle which includes acceptable pairs of break and make times and which has an area considerably larger than that of the diamond. Although certain portions of this rectangle include dial speeds or per cent break values that are unacceptable, it is considered likely that an irregular area within the bounds of the rectangle might be established which would provide somewhat more lenient inspection requirements without impairing the quality of the product. Such an area would be indicated by a template applied to the face of the cathode ray tube. It would

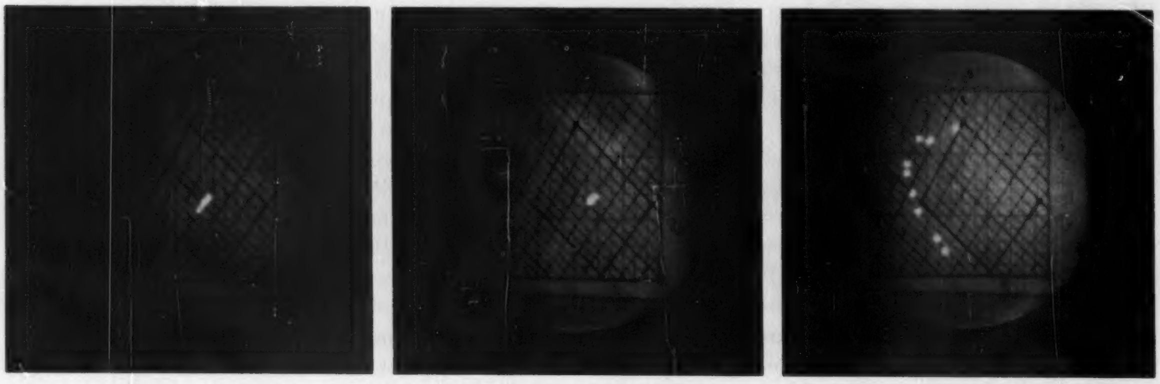


Fig. 2 — Left, dot pattern for dial that has a slight drift in run-down speed. Center, dot pattern showing excellent dial performance. Right, dot pattern for poor dial with variations in speed and per cent break.

require no complicated instructions to the operator of the equipment.

Figure 2 shows the actual dot patterns taken on this equipment when the digit "0" (ten pulses) is used. An acceptable dial having a slight drift (approximately ¼ pulse per second) in speed during run-down is shown in Figure 2, left. The close grouping produced by a very good dial is illustrated in Figure 2, center, and Figure 2, right, illustrates a dial of the older type with variation in both speed and per cent break. These are recorded patterns; actually, the dots appear successively as each break and make cycle occurs during the dial run-down. Also, since the pulsing contacts start and end closed, there are ten measurable break times for the digit "0" during run-down but only nine measurable make times, as the last make ends the run-down. This means that only nine corresponding pairs of break and make times are measurable and accounts for the appearance of only nine dots on Figure 2, right.

The circuitry selected for use in the new dial testing equipment was chosen after considering relative ease of trouble detection, over-all simplicity, accuracy of reading, and simplicity of fundamental calibration. These circuit functions are shown by the block diagram of Figure 3. Break and make times are stored, for simultaneous measurement, as charges proportional to these times on capacitors in R-C circuits. Two pairs of R-C circuits are used alternately to provide time for clearing one time measurement while the succeeding one is being made. An electronic sequence switching circuit, controlled by suitably converted dial pulses, is the control center of the device and performs the following functions: It turns on the appropriate timing gates for the duration of the break and make times of the pulsing contact; directs the operation of the clearing circuit to de-energize the proper R-C circuits after each time measurement; switches the time measuring circuits to the proper capacitors in the R-C circuits, and brightens the oscilloscope spot through an "OR" gate connection to the "Z-axis" (brightness control) of the oscilloscope. The R-C circuits are series arranged resistance and capacitor combinations which are connected to a dc source when the timing gates are turned on by the sequence switching circuit. Thus, the capacitor of the R-C circuit is charged to a voltage proportional to the break or make time during which it has been charged. This voltage is retained until displayed on the oscilloscope. The time measurement circuits measure the voltages on the capacitors of the two R-C circuits to which they are connected by the switching circuit. They are designed to have substantially no effect on the capacitor voltage, and to supply a proportional voltage at low impedance to the oscilloscope for display. The break time voltage is applied to the vertical, Y-axis, and the make time voltage to the horizontal, X-axis, dc deflection amplifiers of the oscilloscope. Spot brightening, referred to above, occurs after the break and make times of a given pulsing contact operation have been completed and stored as voltages on the R-C capacitors. Therefore, the capacitor voltages are fixed and

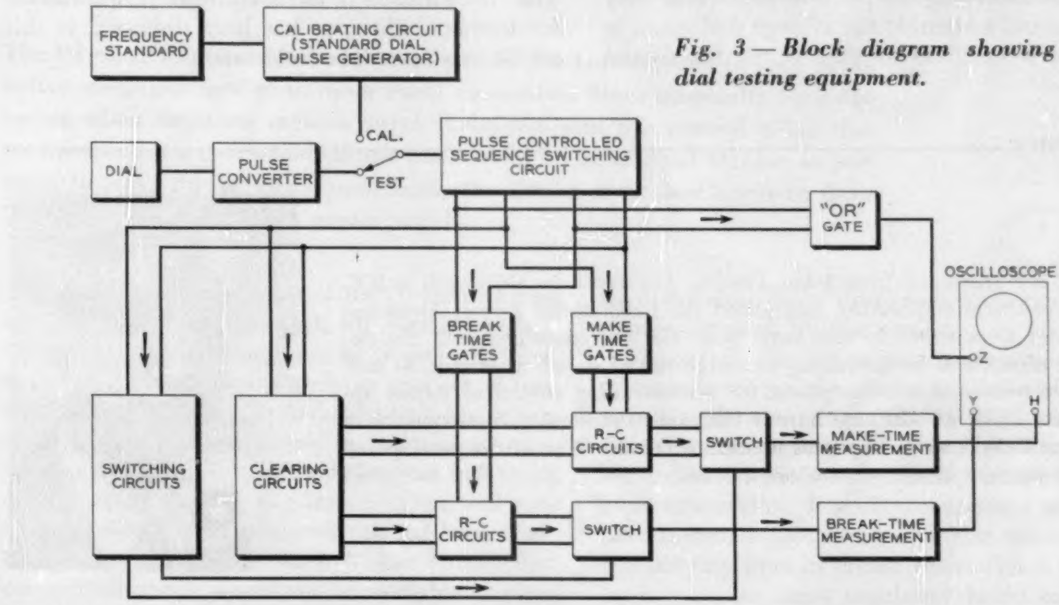


Fig. 3 — Block diagram showing dial testing equipment.

the brightened spot is stationary on the screen.

The calibrating circuit, indicated in Figure 3, produces synthetic, accurately timed dial pulses from a standard frequency supply. Two pulse characteristics are provided having differing "break" and "make" times to provide two spot locations on the oscilloscope. Since these "make" and "break" times are known, it is possible to align the spots with the horizontal and vertical time scales selected for the display. Controls are provided in the circuit for scale alignment.

The advantages of this new measuring method suggested that it might be of value for inspection of dials during manufacture. Present production inspection of the pulsing contact adjustment for conformance with the tolerances previously described is made by averaging the per cent break time over ten pulses and measuring the average dial speed in pulses per second. This method of test has several disadvantages such as the fact that the break and make times of individual dial pulses cannot be determined. Two additional disadvantages are that the precision of measurement is not compatible with the improved dials, and maintenance of the dial testing equipment, particularly the pulse averaging feature, is difficult.

Consequently, at the Indianapolis plant of the Western Electric Company, dial testing equipment based on the Laboratories design has been constructed and steps are being taken to place it in service on the assembly lines. Use of this equipment will make more accurate dial adjustment possible while providing, without loss of time, a more complete analysis of the adjustment required to bring the dial within performance requirements. The establishment of modified testing requirements for telephone dials, as has been discussed in this article, is also under consideration.

THE AUTHOR

FRED WEST graduated from Johns Hopkins University in 1928 with a B.E. degree in electrical engineering, and joined the Laboratories Station Apparatus Development Department in that same year. He was concerned with the development of methods for measuring characteristics of station apparatus, as well as the development of test equipment for manufacturing control of station apparatus until 1953. At that time he was assigned to exploratory development in the Station Development Department. During World War II he participated in the development of devices for military use.

First DEW Building Accepted by U. S. Air Force

The first buildings constructed to accommodate the electronic equipment at a number of sites of the Distant Early Warning (DEW) Line have been completed and turned over to the U. S. Air Force by Western Electric Company. W. H. C. Higgins, Director of Military Electronics Development, represented the Laboratories at the ceremonies.

The present schedule of construction calls for 95 per cent completion this winter of all road networks, air-strip work, buildings and general utility works. Tests of the equipment for this radar network are already under way at several of the sites.

The design of the DEW Line and its equipment was undertaken for the government in 1952 by the Laboratories and the Western Electric Company with advice and assistance from the Lincoln Laboratory of the Massachusetts Institute of Technology. The radome at Whippany was erected to facilitate tests of equipment now in use in the Arctic defense system. The Laboratories participation in the project will continue for a substantial period during the first year of operation.

Power Supplies for the P1 Rural Carrier System

D. H. SMITH *Power Engineering*

The P1 carrier system has been developed by the Laboratories to help bring better telephone service to more rural customers. Since unusually long distances often separate various rural customers and the central office that serves them, the cost of telephone plant must be minimized insofar as possible, to make this service economically feasible. A great deal has been done in this direction in the P1 power supply.

Early in the development of the P1 rural carrier system[1] it was foreseen that, for several reasons, the power supply problem would be difficult. First, there was the knowledge that, in general, a conventional ac power supply to deliver only one or two watts of dc would cost nearly as much as one that delivers 25 watts. Thus, new techniques had to be developed in connection with rectification and control of small amounts of power derived from alternating current. Second, since it was known that commercial power would not be available in some rural areas, an optional arrangement involving prime power supply was required.

The power required by the rural carrier system is quite low. A central-office terminal, for example, draws about 50 milliamperes from standard central-office batteries. Power-supply arrangements here are comparatively simple in that they are limited essentially to the provision of dropping resistors. A remote terminal does not require steady current, but has an average drain of about 40 milliamperes at 22.5 volts. These values of power are as low as that required by our every-day flashlight. A repeater, serving up to four carrier channels, draws about 100 milliamperes at 22.5 volts. In addition, each equipment unit needs a few milliamperes at 16.5 volts for bias. Special power supplies, both ac and battery, have therefore been developed for repeaters and remote terminals for this system.

The rectifier in the ac power supply consists of semiconductor junction diodes in a full-wave bridge circuit as shown in Figure 2. The diodes are small, relatively inexpensive and have fairly stable electrical characteristics with normal variations in ambient temperature. Equally as important as the rectifier is some means of assuring that the output dc will not vary from its proper value. This is provided by a transistor shunt regulator[2] based on a transistor developed by the Laboratories that has a maximum power dissipation of about two watts. A regulator, however, is only as good as the standard against which it compares the voltage or current to be regulated. Instead of the more usual gas tube, the P1 power supply uses a silicon junction diode biased in its reverse direction past the saturation point as a voltage standard.

A storage battery is "floated" across the regulated output to provide emergency power during any possible failure of the ac supply,[3] and to act as a filter to help reduce hum and ripple in the output. This battery, which is kept charged by the regulated dc, has lead-calcium plates and a high specific-

[1] Record, *August*, 1956, *page* 281. [2] Record, *September*, 1955, *page* 344. [3] Record, *December*, 1955, *page* 458.

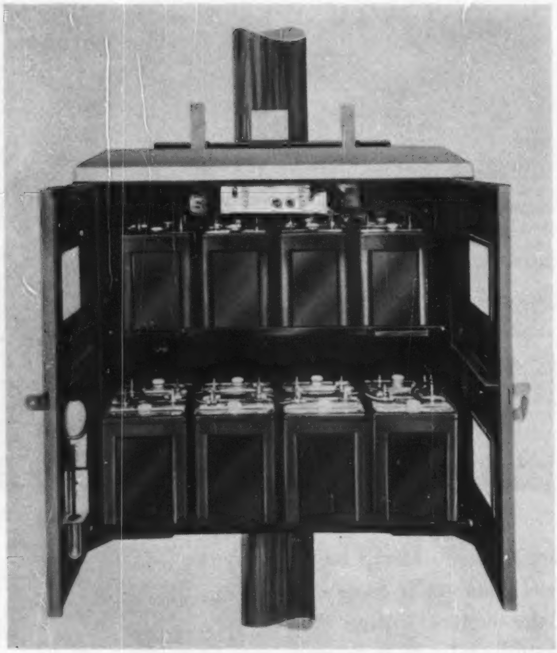


Fig. 1 — Air-cell battery power plant.

appreciable charging current until it approaches a fully-charged condition. Since the high current would be beyond the capabilities of the rectifier in the power supply, the regulator circuit is designed to hold the charging current to a safe value. The regulator provides a constant output voltage until the current requirements exceed a predetermined value. A ballast resistor then automatically limits the current to a safe amount.

The entire ac operated power supply occupies a volume of a little over one cubic foot, about one-third of which is taken up by the storage battery. Although the cost of connecting to ac lines will vary in different installations, the power supply itself is inexpensive and the use of semiconductor devices rather than electron tubes should considerably reduce the annual charges.

A view of the ac operated power supply is given in the headpiece. The entire power plant is housed in a cast aluminum box similar to that used to house a remote carrier terminal. The transistor control network, as shown by the shaded area in Figure 2, is mounted on a printed wiring board which can be removed easily for replacement or repair.

The alternative supply for use when ac is not available consists of air-cell type batteries, Figure 1. These cells provide enough power to operate a remote terminal for about two and one half years and a repeater for a little less than one year. Specially designed to operate in extreme temperatures, the air-cell has a composition case and uses a potassium hydroxide electrolyte, a zinc negative electrode and a carbon positive electrode. The cell is shipped dry to the area in which it will be used

gravity acid solution as an electrolyte. This combination is expected to provide satisfactory performance over a range in temperatures extending from —40 to +140°F. Transparent sides of the plastic case permit the electrolyte level to be seen, and water can be added without removing the battery from the power-supply cabinet.

Should the ac power be interrupted for any length of time, the battery will be partly discharged. When ac power is restored, the battery would draw an

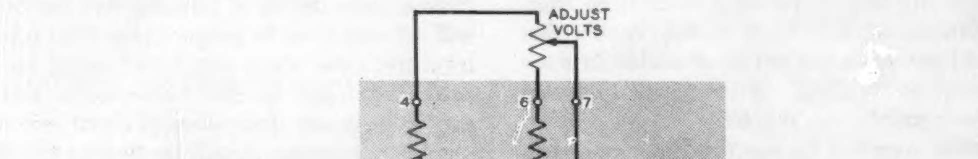


Fig. 2 — Rectifier and transistor control network for P1 power supply.

and water is added on location. After the battery is fully discharged, a new battery is installed.

A preliminary field test of the P1 carrier system was made in Americus, Georgia, during 1954 and 1955. Experimental models of an ac operated power plant and an air-cell battery power plant were tested and several modifications of both plants have been made on the basis of the field test data.

At the present time, investigations are under way on a number of other sources of prime power suitable for applications such as rural carrier. One possibility is the Bell Solar Battery. A storage battery is provided with the Solar Battery to carry the load during periods of darkness, but some energy is received from the sun even in cloudy weather.

An experimental Solar Battery power plant was tested during the Americus, Georgia, trials with the storage battery housed in a separate enclosure near the bottom of a pole. This combination is capable of operating a remote carrier terminal indefinitely, winter and summer, day and night, through bad weather and good with little if any maintenance. The experimental data obtained from the field test indicate the technical feasibility of this type of power system but economic considerations appear to limit its field of usefulness at present.

THE AUTHOR

D. H. SMITH received the B.S. degree in Electrical Engineering from the University of Minnesota in 1944. In 1947, after several years' service with the Military Intelligence Service in Washington, D.C., he joined the trial installation group at the Laboratories. In 1948, he transferred to power development to work on regulated rectifiers. In 1951, he turned his attention to advance engineering and development of power systems, and since 1952, has been in charge of a group concerned with power development planning. Mr. Smith is a registered professional engineer in the State of New Jersey, and is a member of A.I.E.E. and the Amateur Astronomers Association.

First Section of "White Alice" Opens

The first section of "White Alice," a communications network being built in Alaska by Western Electric Company under contract to the Air Force's Air Material Command, was put into operation recently. White Alice, designed primarily to serve North America's defense, will also eventually bring the most remote sections of Alaska within quick and easy telephone contact. The system makes use of over-the-horizon radio relay never before used on such a large scale.

The first completed section connects Anchorage and a military installation 175 miles away on Middleton Island in the Gulf of Alaska. This section also makes available commercial telephone and telegraph circuits for Cordova, an important fishing center. As one of its important defense uses, White Alice will enable combat centers of the Alaskan Air Command to receive reports of aircraft that are detected by radar outposts, including the stations on Distant Early Warning (DEW) Line, north of the Arctic Circle.

The Laboratories supported Western Electric Company in this project by establishing the basic systems engineering information, consulting in the new scientific areas involved and, where necessary, new design and engineering effort. Laboratories members attending the formal opening ceremony in Anchorage on November 29 were: R. P. Booth, H. E. Stinehelfer, W. H. Tidd, H. A. Wenk and F. E. Willson.

Testing Telephone Cords

W. S. ENO *Station Apparatus Development*

Every time you use the telephone, the cord is stretched, twisted and abraded. The amounts are very small but their cumulative effects can eventually render the cord unserviceable. For this reason, the Laboratories is continually striving to improve the various types of cords, in performance, in length of life and in appearance. Two specially-designed machines are the chief tools used by the engineers who test all types of existing and developmental cords. Cords are pulled, stretched, twisted, kinked, bent and abraded in accelerated tests to determine their serviceability.

How many times have you seen a telephone handset cord, through handling by several different people – some left-handed, perhaps – twisted and kinked until you had to straighten it before you could use the telephone? If your telephone set is on a table, desk, or file cabinet, how many times have you inadvertently closed a drawer on the cord? These are but two of the many things that can happen to a handset cord in normal usage. Add to these the possibility of rain from an open window wetting the cord, heat from a too-close radiator baking it, a dog biting it, a cat scratching it, a dropped handset stretching it, or any one of hundreds of unforeseen occurrences and you begin to realize that a handset cord takes a lot of punishment during its life.

The handset cord is the one with which telephone customers are most familiar, but several other equally important types of cords are used in the Bell System. A mounting cord connects your telephone set to its terminal, operators use switchboard and head telephone set cords, maintenance men use patching and test cords, and there is a group of miscellaneous cords used for special purposes. Western Electric anticipates a total production of all types of cords this year in the neighborhood of 38 million. Of these, over 29 million are handset and mounting cords.

To a casual observer, a telephone cord appears to be merely a piece of flexible cordage with suitable plugs or terminals on each end; actually, it is relatively complex. Much design, development and test work has gone into the construction of each type. The size and type of conductors, the insulating material, the jacket material, the type of terminals, the length of terminating leads, even the size, shape and means of fastening the protective grommet at the end – all these must be considered. The materials used must be strong and stable, so that the cords will be flexible and will withstand years of service without breakage of the conductors or wearing through of the jacket or outer braid,

yet the cords must be capable of being easily cleaned and must be pleasing in appearance.

Although a few mounting cords such as those on telephone key-sets having access to several lines,* and perhaps a few other special cords, use stranded wire to achieve minimum size, most cords use what is known as "tinsel" to obtain maximum flexibility together with long life. Several methods of producing tinsel conductors are available, but the most common method is to wrap two bronze alloy ribbons about 0.001-inch thick and 0.020-inch wide around a cotton-thread core. Four or six of these tinsel strands are then twisted together around another cotton core to form a bare tinsel conductor. Usually, the conductor is protected by a knitted cotton barrier before the application of rubber or vinyl-plastic insulation. The required number of insulated conductors are laid parallel and covered with an external neoprene or vinyl jacket. Neoprene or vinyl jacketed "cordage" is manufactured by the mile; when cut to length and finished with the appropriate terminals, plugs and other accessories, it becomes a cord.

Both during the development and afterward, the cords are put through exhaustive tests to determine how they will stand up in service. Although the tests cannot duplicate the normal service life of a cord, special testing machines have been designed to simulate, as nearly as possible but at greatly accelerated rates, some of the things that can happen to cords. These same testing machines and methods are also used in the continual search for better materials. While these laboratory tests cannot simulate all the different kinds of wear and abuse cords receive, they give a good indication of the relative merits of various types of cord and conductor construction. Supplementing these tests, field trials are held in typical heavy-traffic locations in large and medium-sized cities, and also in hot, humid locations. Cords to be used on coin telephone sets are usually placed on trial in busy locations such as are encountered in railroad stations and subway stations.

Two machines have been designed and built to test these cords, one for wear and abrasion of the jackets and braid, and the other, a bending machine, for evaluating conductor life. In the machine shown in Figure 1, several transverse bars located on different vertical levels are alternately moved toward one end of the machine and then the other. One end of each cord to be tested is fastened to one of the bars, and the other end is either left free or attached to a spring-loaded tension indicator. Although sometimes called a "kinking" machine, it is used to test resistance of cords to abrasion. Cords with one end free can be dragged across different types of materials, such as wood, to simulate the edge of a desk, to test abrasion of the jacket. Retractile cords are tested for abrasion in a similar way, except that both ends are clamped.

When one end is attached to the indicator, a cord can be alternately put under tension and released. For retractile cords, this simulates the stretching occurring in normal service. For straight cords, each cord is given a sufficient number of twists to make it "kink" into various shapes before it is placed in the machine. A specified length of cord is used and the number of twists is adjusted so that the machine applies the same maximum tension to all cords under test. The indicator shows how many ounces of tension are being applied. This test combines tension with abrasion, subjecting the cords to two types of strain at once.

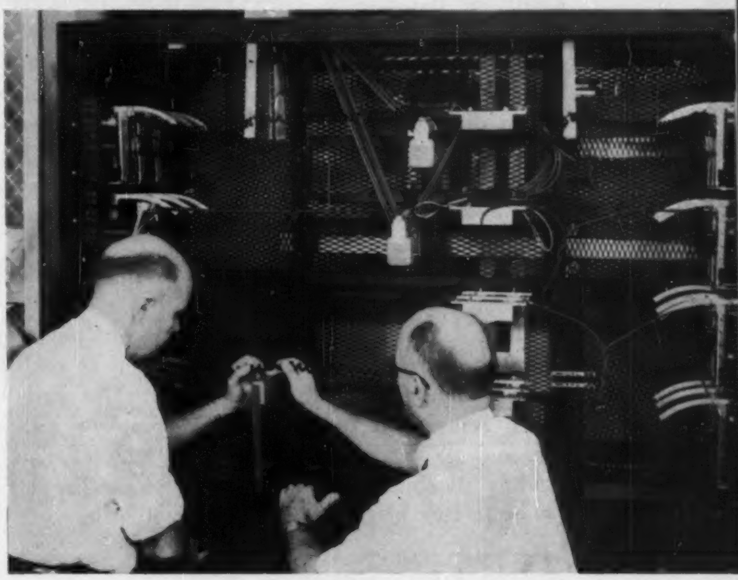


Fig. 1 — The author (left) and C. A. Webber examine a retractile cord being tested for abrasion.

This machine, then, is used primarily to test abrasion and the resulting wear of jackets and braids, as opposed to the bending machine, which evaluates conductor life. A check of conductor life is maintained during wear abrasion tests, but conductor performance is usually still satisfactory when the abrasion test indicates failure of the jacket.

* Record, *June*, 1940, *page* 315.

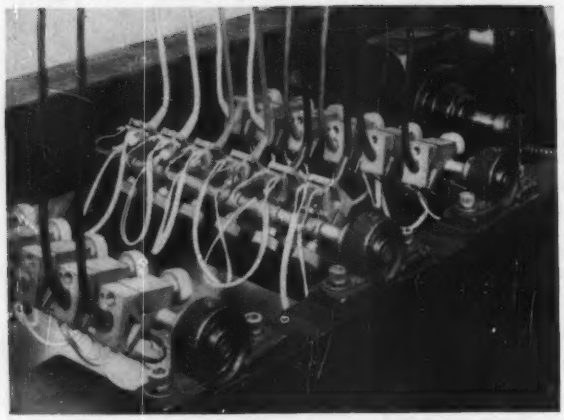


Fig. 2 — Close-up of the bending machine showing cord holders that are employed.

The "bending" machine, shown in the headpiece, simulates the use a cord gets in service. A metal cord holder shaped to exactly duplicate the entry hole holds the handset end of the cord, Figure 2. The cord holder is mounted on a motor-driven shaft, so arranged that the cord must bend from side to side as the cord holder rotates 90 degrees in each direction from normal. About two feet above the cord holder, the other end of the cord is attached to a metal spring that applies tension to a section of the cord. A weight, usually one pound, is hung from one of the springs to give a standard spring deflection, and the cord length is adjusted to give that spring deflection at each extreme of rotation of the cord holder. The cords under test are flexed through a complete 180-degree cycle at the rate of 36 times a minute. The bending machine also tests the serviceability of the protective grommet associated with the cord.

Cords are placed in the machine with a predetermined twist, either right or left. A line marked on the untwisted cord indicates the direction and amount of twist when the cord is in the machine. Although this simulates the twisting a cord may be subjected to in normal service, it cannot give the final answer as to the best construction for all conditions, since there is no way to predetermine in which direction a customer will twist the cord. This is where the Laboratories' supervised field trials play an important part. In addition, detailed examination and study of other cords removed from service and sent to the Laboratories present a good opportunity to determine how cords could be improved for longer service. As with the other test machine, the conductors are electrically checked during the bending test.

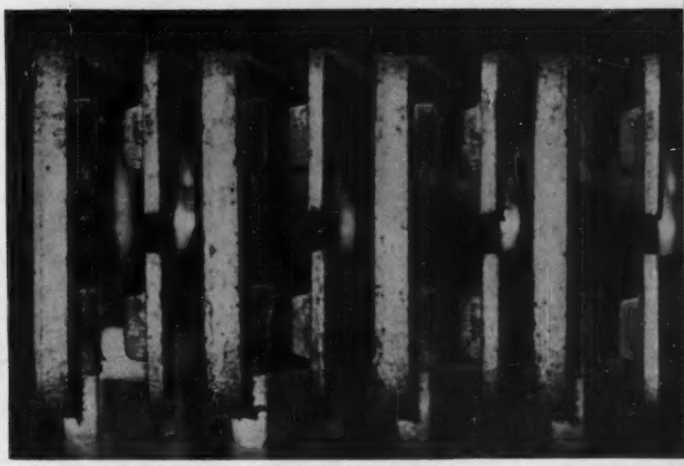
To check for conductor life, the two conductors of each pair are connected at the end attached to the moving part of the machine being used. The other ends are brought out through a plug and cable to a test panel where a Wheatstone bridge can be connected across the pair that is to be tested.

After a given number of bends or stretches, as the case may be, the machine is stopped and the bridge is balanced with the cord serving as one of the bridge arms. Physical manipulation of the cord will then indicate any variations in resistance of the cord. The meter of the bridge is calibrated in fractions of an ohm, and variations indicated by the meter result from resistance changes that may be heard as cord "noise" in a telephone receiver. The number of test machine operations before the noise exceeds a predetermined amount gives a relative measure of the conductor life.

THE AUTHOR

WILBER S. ENO received his degree in Mechanical Engineering from Rensselaer Polytechnic Institute in 1935 and joined the Laboratories early the following year. His work has been primarily in the field of station apparatus development on such items as combined telephone sets, explosion-proof telephone sets, and other customer apparatus. He also engaged in the engineering and design of telephone sets, headsets and loudspeakers for the Armed Forces. From 1938 to 1942, Mr. Eno was a member of the Quality Assurance Department, including an assignment to Cleveland as Assistant Field Engineer. He also spent the years from 1945 to 1948 in Quality Assurance, working with teletypewriter apparatus. From 1948 to 1956 he was engaged in the design of all types of telephone cords. In January, 1956, he transferred to the Laboratories location at Indianapolis where he is now engaged in the design of telephone sets. Mr. Eno is a licensed Professional Engineer and a member of Sigma Xi.

Dust on Relay Contacts



H. J. KEEFER
Switching Apparatus Development I

As one wanders among the thousands of busily clicking relays in a telephone central office, it is difficult to realize that a major enemy of good telephone service is plain, every-day dust. Housewives scour away dust for appearance's sake, but telephone maintenance personnel know that the reduction of dust in the office can decrease their work considerably. Open-circuit contacts, manifesting themselves to the customer as delays, wrong numbers, or even lack of service, are a possible result if dust is not held to a minimum.

The story of contacts* – switching contacts in the case of telephone systems – cannot be complete without a complementary story of dust. What is dust? Dust is that fine greyish coating that covers everything in the house and office. It is such a major problem to the housewife that huge industries have been built just to manufacture appliances and gadgets to alleviate her plight. To the housewife, dust is primarily a problem of appearance. To the telephone maintenance man, dust is a more serious problem since excessive dust on relay contacts can create operating difficulties.

Dusts may be broadly classified as externally or internally generated. Externally-generated dusts such as cinders, coke particles, flyash, soot and mineral matter can usually be kept to a minimum in a telephone office by the use of filtered ventilating systems. Internally-generated dusts such as textile fibers, wood and pulp fibers, epidermal scale, apparatus wear products and contamination from manufacture and installation are generally considered to be the most detrimental from a contact reliability standpoint. These internally-generated dusts, some of which are caused by personnel activity, are the most difficult to eliminate.

Dust consists mostly of non-conducting particles which, when allowed to accumulate on contact surfaces, may cause open-contact failures. The word "may" is used because a contact surface can be apparently covered with dust but, unless the actual point of contact becomes insulated, a failure will not occur. An open-contact failure occurs when mating contacts in their closed position have: (1) a resistance that limits the current to a value less than the minimum required for proper circuit operation, or (2) an infinite resistance, resulting in no current in the associated circuit. An open contact can cause a variety of circuit reactions ranging from complete stoppage of a circuit to the use of alternate circuit paths. The results to a customer can be a temporary disruption of service, a wrong number, or an additional wait while a call is completed.

Contact performance, with respect to open failures due to dust, varies with the contact design, how the contact is used in the circuit and the surrounding environment. Design factors include: the type of contact metal, the contact shape, the contact forces, the method of actuation, the physical orientation and whether the contact is single (two pieces of contact metal that mate) or twin (two single contacts in parallel). A contact may be used either normally open or normally closed, with various current and voltage conditions, and in a slow- or fast-oper-

* Record, *February*, 1949, *page* 50.

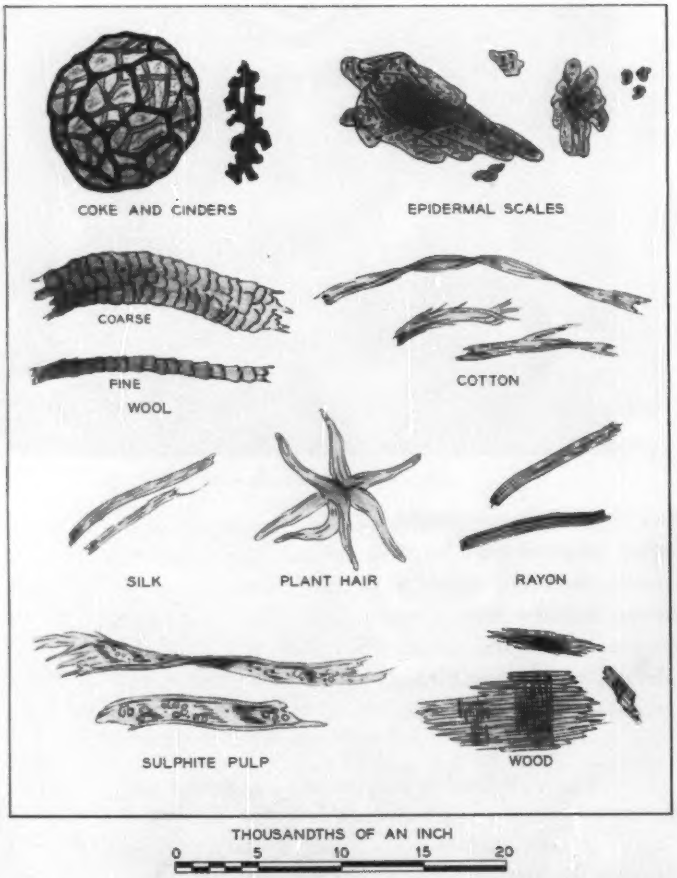


Fig. 1 — Some types of dust that can affect contact operation. The area is approximately that of a U-type contact.

ating circuit. The contact may be used uncovered or under varied cover conditions, and in switchrooms with different degrees of cleanliness.

Generally, a contact has to perform one of two functions in a circuit: (1) it must make and/or break the current, or (2) carry the current only without making or breaking it. The former, or "working" contact, is the least affected by dust since arcing at the contact surfaces is a form of cleansing action. The latter, or "non-working" contact, is most susceptible to failures due to dust since no arcing occurs on the contact surfaces.

Open contacts due to dust on relays are more likely to occur in the older switching systems. The E- and R-type relays of the panel system and the 221- and 222-type relays of the step-by-step system have single contacts and are therefore more likely to cause circuit failure. Because of this, the older systems require a great deal of contact maintenance to give adequate service.

Part of the progress in the development of modern switching systems in the 1930's was improvement in relay design. The U-type relay introduced in the No. 1 crossbar system provided twin contacts. The parallel action of twin contacts decreases the probability of contact failure since it is less likely that both contacts will fail simultaneously. Depending upon the rate of operation, a twin contact is 10 to 100 times as reliable as a single contact. This is particularly important since approximately 75 per cent of the relay contacts in crossbar systems are non-working contacts and are therefore susceptible to open-contact failures. It has been said that with the type of circuitry used in modern switching

Fig. 2 — The author makes a further electrical check of a relay contact that has registered "open".

systems, operation would be practically impossible without the use of twin contacts.

A "replica" technique,* developed to investigate the causes of contact failures due to dust, permits making a plastic impression of a contact and simultaneously removing surface films and dust onto the small piece of clear plastic. The replica may then be microscopically and chemically analyzed at any time and at any convenient location to record the sizes, quantities, types and locations of dusts on a contact surface. By this means a knowledge can be

* RECORD, *August*, 1956, *page* 289.

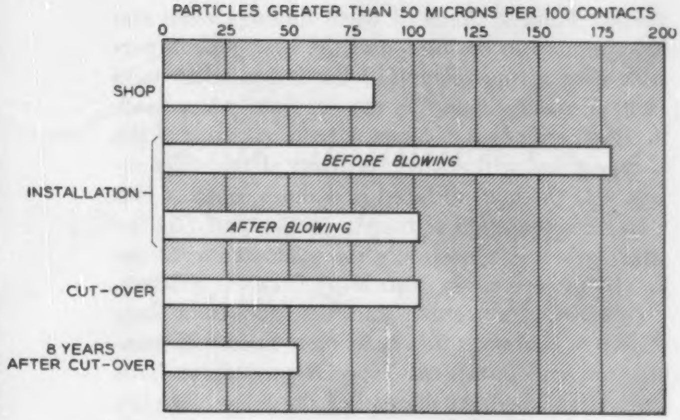


Fig. 3 — Contamination history of contacts.

gained as to types and classifications of dust, and how and when dust can cause a contact to fail.

Using this technique, an extensive dust survey to determine the extent of contact contamination during the manufacture, installation and operation of switching equipment revealed that the greatest degree of contamination occurs early in a contact's history, Figure 3. Thereafter, a contact located near a center of personnel activity, such as a test and maintenance section of a telephone office, is most exposed to contamination. It was also found that the standard practice of pressure cleaning relays in a telephone office removes loose dusts — potential causes of contact failures — from contact vicinities, but it does not remove impacted contamination from contact surfaces.

Fig. 4 — W. L. Bacom installs turret in dust meter.

Special laboratory test equipments were designed to augment field studies. One of these, commonly called a "dust meter" but affectionately called the "coffee grinder", is used as a tool to provide basic knowledge in the classification of dust particles with respect to contact failures. The construction of the test machines, Figure 2, is such that various types of controlled dust or types of filtered air may be symmetrically circulated or drawn across the contacts located in the turrets, Figure 4 and 5. The turret or chamber insures that the contacts are only subjected to the desired atmosphere under test.

An analysis of the many exploratory tests conducted with the dust meters and substantiated by field studies revealed some worthwhile relationships between contact troubles, and dust. Open-contact failures are usually caused by fibrous or other par-

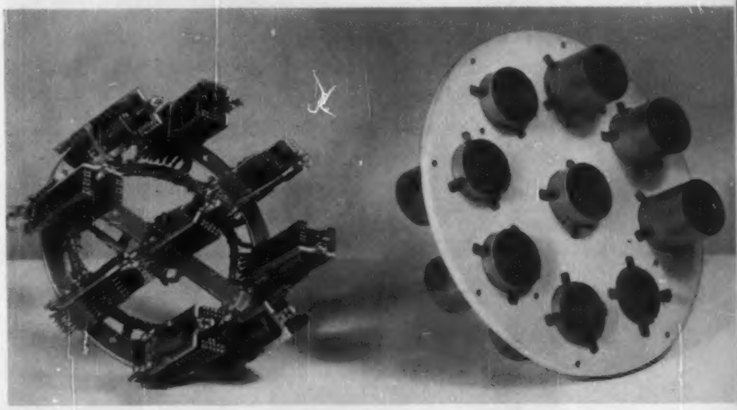


Fig. 5 — Relays mounted in this turret are checked in the dust meter of Figure 2.

ticles greater than 50 microns (approximately 0.002 inch) in size. Finer dust does not generally cause contact failures unless the particles compact to form large aggregates. Relative humidity affects the physical properties of dust so that open-contact failures decrease with an increase in humidity. It would seem that small tight enclosures around relays would exclude extraneous dusts and a series of enclosure studies did indeed show that compartmentation would reduce the circulation of air-borne dusts by "chimney" effects. When, however, non-working palladium contacts were operated in tight compartments, the number of contact failures increased rather than decreased. The reason was found to be "brown powder."

Brown powder, as the name implies, is a powdery organic polymer formed on a non-working contact by a reaction of organic vapors on palladium or platinum contacts at the time of contact friction.

Although not classified as dust, brown powder is an effective insulator and on a contact surface has the same effect as dust. But, it was found that a tight enclosure that reduces open-contact failures due to dust causes an increase in contact failures due to brown powder. The reason is that the tighter the enclosure, the greater the concentration of organic vapors (produced mainly by heating of the relay coils by the current through them) in the vicinity of the contacts; this results in greater quantities of brown powder. The majority of relays in a telephone switching system have palladium contacts and hence are vulnerable to brown powder failures. Relay contacts of other metals such as gold and silver do not generate brown powder, and consequently they can be protected against dust by tight compartmentation in contact covers.

The many phases studied on the subject of dust and its effect on relay contacts are as varied, yet as closely intermixed, as the accumulations found in the dirt collector bag of a vacuum cleaner. However, from this mass of information, many findings were sifted out and applied to existing relays in telephone offices, thereby substantially reducing contact failures. Some of these findings were also incorporated in the design of the new general-purpose wire spring relay: (1) the independent twin contact action, owing to the separate wires used, is far superior to the "Siamese twin" contacts of the U-type relay or the single contacts of the older relays, (2) the gold-surfaced palladium contacts prevent the generation of brown powder and (3) the cover, which encloses only the contacts on the relay, keeps extraneous dusts away from the contacts.

In addition, since a contact may acquire a large degree of contamination in its early history of manufacture and installation, special procedures have been established. At the end of the relay assembly line, the contacts and surrounding areas are scrubbed in a trichloroethylene bath; this process removes 95 percent of the shop contamination. The contact cover is then put in place, and thereafter protects the contacts during wiring at the shop and subsequent installation and operation in a telephone office. As a result of this procedure, the new AF, AG, and AJ wire-spring relays that are used in switching systems today are almost free from open-contact failures.

THE AUTHOR

H. J. Keefer joined Bell Telephone Laboratories in 1928 as a messenger and later a draftsman, and left in 1932 to attend the Georgia Institute of Technology where he received the B.S. degree in Electrical Engineering in 1937. Upon his return to the Laboratories, Mr. Keefer was engaged in the laboratory testing of step-by-step system PBX's, and for two years, long-line pulsing circuits. After five years' service in the Artillery and Signal Corps during World War II, he returned to the Laboratories in 1946. Since that time he has been engaged in erosion studies, life studies and open contact studies on telephone relay contacts.

F. A. Polkinghorn Elected Director of I.R.E.

Frank A. Polkinghorn, a member of the Military Systems Studies group, has been elected a Director of the Institute of Radio Engineers. Named to the I.R.E.'s governing body recently, he will represent Region 2 which consists of the New York metropolitan area.

A graduate of the University of California, Mr. Polkinghorn joined Bell Telephone Laboratories in 1927. In 1948 he joined General MacArthur's staff while on leave from the Laboratories and served as Director of the Research and Development Division, Civil Communications Section, General Headquarters, Supreme Command Allied Powers. In this position he had supervision of all Japanese communication research, development and manufacturing. In recognition of his contributions, he was named an Honorary Member of the Institute of Electrical Communication Engineers of Japan. He returned to the Laboratories in 1950.

Mr. Polkinghorn is a Fellow of the I.R.E. His other affiliations include A.I.E.E., A.A.A.S., Phi Beta Kappa, Tau Beta Pi, Sigma Xi, and Eta Kappa Nu.

Atomic Radiation Used To Study Growth Of "Whiskers" On Metals

C. J. Calbick, left, and S. M. Arnold get a closeup view of the make-up of some metal whiskers through an electron microscope.

More than five years ago research at the Laboratories indicated that microscopic metal "whiskers" had literally grown on some types of telephone equipment and had caused short circuits. The discovery of these metal whiskers opened a new avenue of scientific research and thousands of tests were made at the Murray Hill Laboratory.

X-ray studies made of the crystal structure of whiskers have shown that they are, in fact, single crystals. Such studies reveal the crystal direction in which whisker growth takes place. These crystals were also shown to possess great strength by C. Herring and J. K. Galt of the Laboratories in 1951. The results of such studies on the structure and properties of whiskers are being used to gain a fundamental understanding of how whiskers grow.

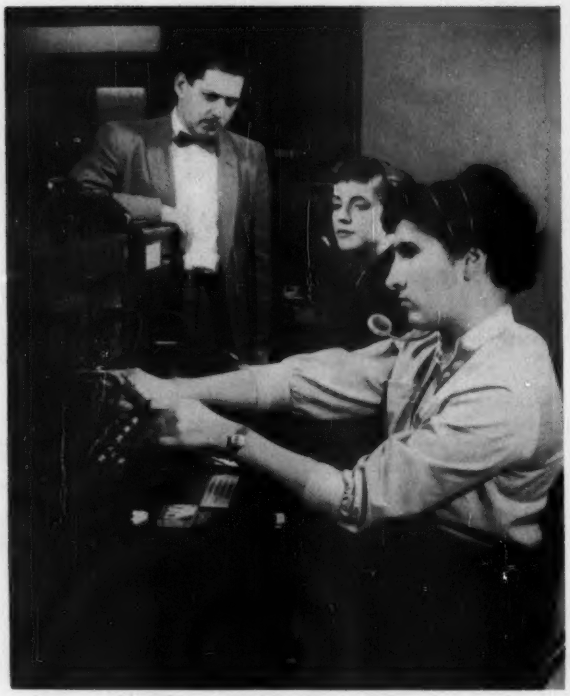
The whiskers on some metals do not grow large enough to be seen through an ordinary miscoscope, and an electron misroscope provides the only way of determining their growth. On other metals which grow large whiskers, the electron microscope detects sprouting before the whiskers are large enough to be seen through an ordinary microscope.

Some time ago, Laboratories scientists speculated that whisker growth might be affected by neutron bombardment. Samples of tin were, therefore, placed in the reactor at the Brookhaven National Laboratory and removed a month later. Examined recently after a year of "cooling off," the irradiated samples were found to have grown more whiskers than identical ones on shelves, in ovens and in cold chambers at Murray Hill. Damage to the crystal structure of the metal caused by the neutron bombardment had increased the tendency of the samples being tested to produce the minute filaments. The test of the effect of atomic radiation, latest of an extensive series conducted by S. M. Arnold of the Metallurgical Research Department, is but one part of a general program of metal whisker research being carried out at Bell Telephone Laboratories.

With the increased use of tiny electronic parts likely in the telephone industry and elsewhere, whiskers could cause short circuits between minutely spaced metal surfaces. Therefore, telephone scientists know that design of new electronic equipment must take into consideration the whisker-growing potentialities of various metals.

Although whisker growth is a new field of research, there have already been tangible results in the form of recommendations concerning the use of some metals. Bell Laboratories scientists found whisker growth on platings of zinc, tin and cadmium used as finishes in telephone apparatus. In critical Bell System circuit applications where whiskers could cause short circuits, these platings have been discontinued and metals not susceptible to whisker growth at operating temperatures have been substituted. Gold plating was recommended for use instead of tin in the repeaters of the transatlantic telephone cable, which went into commercial operation recently. In extensive tests, gold had been found to be whisker-free under operating conditions. Whisker-proof plating metals are also used in the metal can assembly of the transistor.

Bell System Aid to the Blind



S. B. Weinberg and Miss Judith Shaver, operator-instructor, watch as Miss R. Portelli, blind operator-trainee, locates the light of an incoming call with the phototransistor finger probe and prepares to complete the connection.

From time to time developments made by the Laboratories for Bell System communications systems find applications far afield from the original design purpose. A recent example of this is the phototransistor used in the Bell System card translator for direct distance dialing. In fulfilling a request by the American Telephone and Telegraph Company, Laboratories engineers are experimenting with the phototransistor as the basic unit of a "Seeing Aid" designed to make it possible for blind attendants to operate a variety of PBX's. This seeing aid is now being tested by blind trainees at the New York Telephone Company.

The problem of helping blind personnel operate PBX switchboards has always received sympathetic Bell System attention. Blind attendants were capable of operating the early designs of PBX switchboards since signals to the attendant were given by mechanical drops (pieces of metal which dropped from a vertical to a horizontal plane). The attendant would only have to locate the activated drop to identify the line, trunk or cord signal and thus be able to take the necessary action.

With the introduction of switchboard lamps, the difficulties of blind PBX attendants were greatly increased. To alleviate this situation, the Bell System developed and produced a system employing solenoids with Braille designations which are physically attached to a PBX for operation by the blind. This attachment contains rows of button indicators, each button being a multiple of a switchboard lamp. When a call from a station or trunk is originated, a buzzer in the switchboard sounds and the button associated with the calling station or trunk pops up. If a cord supervisory signal is received, a buzzer in the indicator box is sounded. The attendant's fingers are moved over the rows of buttons until she finds the one that is raised. The Braille designation on the panel above the button identifies the respective line, trunk or cord and the attendant can perform the required operations. This system, although still in use, requires extensive modification of the PBX. Also, its design is at present coordinated only with certain older PBX's.

To extend the usefulness of blind attendants, the Laboratories undertook a study of various proposals, originating within the Bell System and from outside sources, for devices to permit standard PBX and key equipment to be operated by blind personnel. Of the many proposals considered, one that originated outside of the Bell System appeared to

be the most attractive. This proposal involved the use of a photoelectric probe to identify PBX lamps. By properly applying this concept, it was thought that it would be possible to equip the attendant instead of the PBX. This would minimize the cost and time involved in adapting a PBX for blind attendant operation.

The exploratory work that followed resulted in an experimental model of a transistorized, self-contained "seeing aid" unit. This unit, as shown in Figure 1, consists of a finger mounted phototransistor which causes a tone signal to be generated by an associated oscillator when a light is detected. The tone signal is transmitted to the attendant through her headset.

When a call comes into the PBX, a buzzer indicates its presence, a solenoid-operated sectionalizing device localizes the signal to a particular field of lamps, and the attendant scans this field of switchboard lamps with the finger-mounted detector to locate the lighted lamp. When a lighted lamp is encountered the light activates the phototransistor and the attendant hears a signal tone in her headset. She then plugs a cord into the jack associated with the lighted lamp to complete the call. The attendant can detect flashing supervisory signals in a similar manner.

The circuit of this arrangement, shown in Figure 2, consists of a negative resistance transistor oscillator. When light shines on the phototransistor, its impedance decreases sufficiently so that the cir-

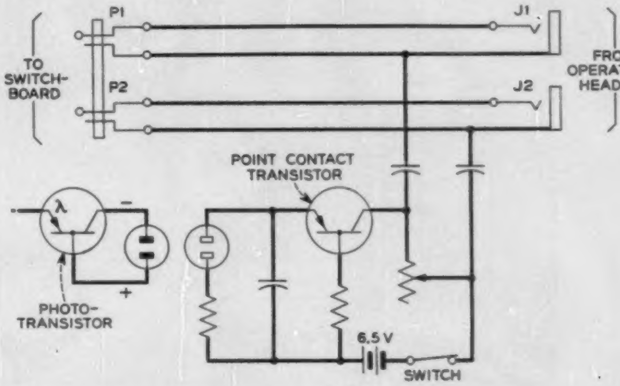


Fig. 2 — Schematic diagram of "seeing aid" circuit.

cuit will oscillate. The signal produced at the collector of the point-contact transistor is introduced to the receiver in the attendant's headset through two 0.02 microfarad coupling capacitors. Its component parts include a point-contact transistor, a phototransistor, two resistors, one miniature potentiometer and switch, three capacitors and one 6.5 volt mercury-cell battery. All components except the phototransistor are mounted in a plastic case designed to plug into the attendant's jacks on the switchboard and to have the attendant's headset plugged into it. The phototransistor is attached to a miniature polarized socket and encased in a neoprene sheath. This unit measures ¾ of an inch in length, ⅝ of an inch in width, and the depth tapering from ¼ of an inch in the rear to ⅛ of an inch in the front. This is mounted on an open ring made of spring steel. The ring is made only in one size and is intended to fit over any conventional size of sewing thimble. The finger assembly is connected to the circuit in the case by means of a 4-foot length of plug-ended flexible cable.

As mentioned earlier, the equipment now in use is limited to only a few PBX's. With the "seeing aid," however, it is hoped that blind attendants will be able to operate all standard PBX's and key equipment. Exploratory field trials with the "seeing aid" used by blind attendants are now under way.

S. B. Weinberg
Special Systems Engineering I

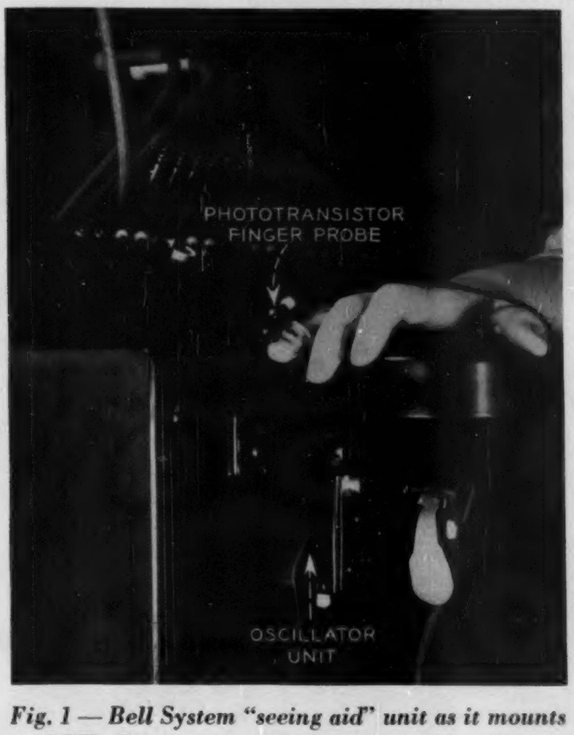


Fig. 1 — Bell System "seeing aid" unit as it mounts on PBX. Finger-mounted phototransistor and operator's headset are connected to plug-in oscillator unit mounted with standard 153A amplifier.

Birger Ekeberg, Grand Marshal of the Swedish Royal Household and President of the Nobel Foundation, addresses the audience at the Nobel Award ceremony in the Stockholm Concert Hall.

Nobel Prizes Awarded in Sweden

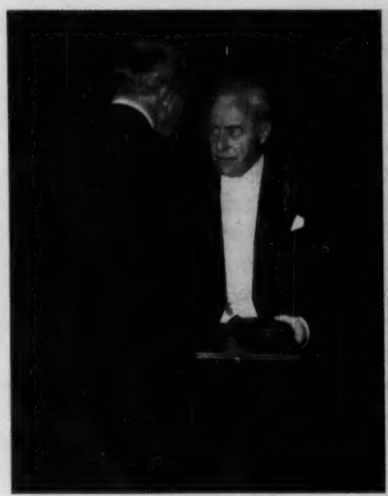
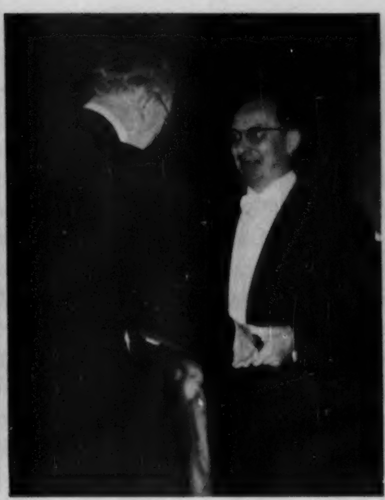
STOCKHOLM – *By Special Correspondent* – W. H. Brattain of the Bell Telephone Laboratories Physical Research Department, and J. Bardeen and W. Shockley, both former members of the Laboratories, received the coveted Nobel prize in Physics on December 10. The award was presented by King Gustav VI Adolph of Sweden in a traditional annual ceremony amid pomp and splendor in the Stockholm Concert Hall.

Each of the three winners of the physics prize received a gold medal, a diploma bound in leather and a third of the $38,633 prize money for their discovery of the transistor.

Dr. Bardeen is now a professor of physics and electrical engineering at the University of Illinois and Dr. Shockley is Director of the Shockley Semiconductor Laboratory of Beckman Instruments, Inc., Mountain View, Calif.

The ceremony in the Concert Hall got under way punctually at 4:30 o'clock when the King, Queen, Princess Sybilla, widow of the late Crown Prince Gustav Adolph, Prince Bertil, son of the King, and Prince Wilhelm, brother of the King, made their entry while a royal fanfare was sounded by buglers, one of the few remnants of pomp in this democratic, socialist kingdom. They took their places in the front row, slightly ahead of the audience. Members of the families of the prize winners sat to the right and left and slightly behind the royal family.

Queen Louise and King Gustav VI Adolph of Sweden greet Miss Constance L. Richards, daughter of Nobel prize-winner Dickinson W. Richards, at the dinner for Nobel prize winners and their families.


Winners of the Nobel Prize in Physics, left to right, W. H. Brattain, J. Bardeen and W. Shockley receive awards from King Gustav VI Adolph of Sweden at ceremonies in the Stockholm Concert Hall.

In his opening address, Birger Ekeberg, Grand Marshal of the Royal Household and President of the Nobel Foundation, recalled that it was the sixtieth anniversary of the death of Alfred Nobel, Swedish inventor of dynamite whose will established the Nobel prizes.

Speeches explaining the awards and praising the recipients for their achievements were made by specialists in each field. First to receive their awards were the trio of researchers from Bell Telephone Laboratories. Professor Erik Rudberg, speaking to them, concluded his remarks in English, saying:

"The summit of Everest was reached by a small party of ardent climbers. Working from an advance base, they succeeded. More than a generation of mountaineers had toiled to establish that base. Your assault on the semiconductor problem was likewise launched from a high altitude camp, contributed by many scientists. Yours, too, was a supreme effort – of foresight, ingenuity and perseverance – exercised individually and as a team. Surely, supreme joy befalls the man to whom those breathtaking vistas from the summit unfold. You must have felt it overwhelmingly. This joy is now shared by those who labored at the base. Shared too is the challenge of untrodden territory, now seen for the first time, calling for a new scientific attack."

At the close of Professor Rudberg's remarks, the three physics winners, one at a time, descended the half dozen steps from the stage to the floor of the Concert Hall where the King was standing waiting. Each bowed, shook hands with the King, exchanged a few inaudible words, received the medal and diploma and carefully sidestepped in front of the Queen, still facing the audience, before returning to his seat on the stage.

The audience heartily applauded each recipient as the prizes were awarded. The ceremony was interspersed with music and the blowing of trumpets as the King made each new presentation.

Two other Americans, Dr. Andre Cournand and Dr. Dickinson W. Richards, both of New York, shared with the West German Dr. Werner Forssman, the prize in medicine for their heart research. Three other prize winners were the Russian, Nikolai Semenov, Director of the Institute of Chemical Physics in Moscow, who shared the chemistry prize with the Britisher Sir Cyril N. Hinshelwood, and the Spanish poet and author Juan Ramon Himenez who was awarded the prize in literature but was unable to attend because of his wife's recent death.

The traditional festivities were curtailed to some extent this year because of the "suffering in Europe," with particular reference to events in Hungary. The prize awarding ceremony was followed by an informal dinner at the headquarters of the Swedish Academy in the Stock Exchange Building in the old city of Stockholm, replacing the customary larger banquet and ball in the City Hall. Besides the prize winners and their families, the dinner was attended by 125 guests including the royal family, the cabinet and members of the Societies which name the Nobel Prize winners. It was followed by serenading by the Stockholm Student corps.

A.T. & T. President Frederick R. Kappel Discusses Future of Communications

An exciting new look into the future of communications was revealed by A. T. & T. President Frederick R. Kappel in a talk before the Economic Club of Chicago on November 15. Pointing to the certainty that Americans will want and use a great deal more communication service, Mr. Kappel pledged the all-out effort of the Bell System to anticipate and meet those needs.

In new developments in transmission technique – which eventually may permit up to 400,000 conversations at the same time along a "wave guide" – and in the relatively new field of electronic switching, Mr. Kappel sees far-reaching effects on the whole communications system.

He said, "To be able to make the best progress, and apply our new tools to the greatest advantage of everybody, the telephone system must be in good shape financially.

Following are other excerpts from his talk:

The telephone business just about begins with getting the money to build the things we need to give the service. On November 5 we finished selling $570 million of A. T. & T. stock. Last July we sold $250 million of bonds. A year ago at this time we were selling $630 million of convertible debentures.

This is the kind of money required to help pay for all the telephones and cables and dial systems and other equipment we expect to install next year. Altogether, in 1957, we plan to spend some two and a half billion dollars for new construction. So far as I know it's much the largest program ever undertaken by any business.

I'm sure this tells you that we in the Bell System have a lot of confidence in the future. We are certain that Americans will want and use a great deal more communication service, and we're going all out in our effort to meet and as much as possible anticipate their needs.

Now I suppose it would be easy for someone to assume that with a rising population, and a higher standard of living, all a company like the telephone company needs to do is accept the business it is offered and enjoy a practically automatic growth.

We don't expect anything of the kind. We know our growth will *not* happen of its own accord, and we have no idea whatsoever that our future increase in business will fall neatly into our laps.

I'm sure the folks who make automobiles wouldn't be selling millions of new cars every year if they didn't keep improving the cars. The telephone business is no different . . . We expect and intend to give Americans a much fuller service, a more complete service, and a greater variety of service, including new services over and above what we are providing today.

By now everybody knows (I hope!) that we have telephones in color. We also have them with loudspeakers so you don't have to lift the receiver. We have automatic devices to answer the phone when you're out. We're developing new telephones specially designed for use in the bedroom, out in the patio, or wherever you are. With equipment available right now, we're trying out a home communication system that will handle calls in the usual way, enable you to talk from any phone in the house to any other, and also permit you to answer the doorbell, when it rings, by talking from any telephone to a loudspeaker by the door. We have other long-range developments under way which we are convinced will have profound and far-reaching effects on the whole communication system.

There are two basic fields for communication research. One is transmission. The other field for our research is switching.

In transmission, one of the important things that has been taking place is this: Step by step we've been able to send more and more information over physical structures used in long distance service.

All this progress has depended largely on vacuum tubes. Now, however, we are beginning to get a new family of electronic devices that don't come in tubes. One of them I'm sure you've heard of – the transistor – invented at Bell Laboratories several years ago.

The Laboratories have been developing new ways for sending information from place to place. We know for instance that we can take a continuous sample of any kind of information – words, pictures, or music – and translate it into a code. These codes consist solely of pulses. They go so fast – in millionths of a second – that when we interleave them or sandwich them, so to speak, we can carry a lot of coded messages all at once. Then at the distant end, each original message is accurately recreated.

We even have the means now to measure the efficiency of different coding systems. I won't go

into this "information theory," as it is called, because it's pretty deep.

With transistors — with new ways of sending information — and with a fundamental concept for testing the efficiency of any transmission system — we're sure that in years to come we'll be able to mass-produce *local* pathways of communication as we now mass-produce *long distance* pathways. This will have enormous consequences.

Even short of full mass-production, multiplying local communication paths should make a lot of things possible that are not possible now. Today, for instance, if you want two or three local telephone lines out to your house, instead of only one, we must use additional wires. But the day is coming when we can add the lines without adding the wires.

We also have some very exciting further prospects for mass-producing the longer lines. For 25 years a group at Bell Laboratories has been working out a way to transmit really huge quantities of information through what we call a "wave guide." A wave guide is nothing more or less than a hollow copper tube — very finely made, to be sure, but a hollow tube nevertheless. We expect a pair of these tubes will be capable of transmitting electrical waves that vibrate or pulse at speeds up to 60,000 or even 70,000 *million* times a second. Now, when we send those coded samples I was talking about through wave guides — with that kind of system we expect to be able to send as many as 400,000 telephone conversations at the same time.

Already we see the need for transmitting tremendous amounts of raw data. The age of data processing has just begun. We expect that as time goes on the amount of communication between machines in different cities may be as large as the amount of communication between people.

Now let's consider switching. We're working on a new kind of switching system. We call this *electronic* switching. Transistors and several other new kinds of electronic devices will do the brainwork.

I said brainwork deliberately, because this system is really a computer; a special kind of electronic computer that is tied in with a switching network. It has a memory — in fact it has two kinds of memory, permanent and temporary — and it also uses logic. I might add that it functions rather quickly, in pulses of one or two millionths of a second. This is about 100,000 times faster than you can wink your eyes; and it's fast enough so that to each telephone user the effect is continuous. Hence, while one series of pulses is serving one person, other pulses in the same unit of equipment can be serving other people at the same time.

As nearly as possible, we want to build a communication system that will do anything people could ask of it.

Rome wasn't built in a day and these things will take time too. We're confident they are practical but that doesn't mean we can do them all at once. We'll make some progress in five years, more in ten, and even more in twenty. Remember, this is pioneering, and the process of transforming a nationwide system is bound to be an evolution.

Finally, I hope you won't take away any impression that the telephone companies are trying to build an automatic wonderland. These new electronic arts will only be as useful as human beings are able to make them. They will provide services that are attractive and pleasant to use, only as telephone people do their very human best to meet the human needs of others. And these are the ways to more jobs, not less — more skills, not less — more pleasure and satisfaction in accomplishment.

This "talking path" tube, only 1½ inches long, is a possible "switch of the future" for experimental all-electronic switching systems.

Dr. Kelly Chairman of Committee To Honor Enrico Fermi

Dr. M. J. Kelly will serve as Chairman of a committee to establish a professorship in honor of the late Enrico Fermi at the University of Chicago.

To perpetuate and memoralize the scientific contributions of this world renowned nuclear physicist, The University of Chicago plans to establish "The Enrico Fermi Distinguished Service Professorship" at the Institute of Nuclear Studies where Dr. Fermi taught and carried on his research.

Often referred to as "the architect of the atomic age," Enrico Fermi is perhaps best known as the first man to achieve the controlled release of nuclear energy. His classic experiment in this field was carried out at The University of Chicago where, on December 2, 1942, the first controlled nuclear chain reaction was demonstrated. Other of his many achievements include studies which led to artificially produced radioactivity and to the control of thermal neutrons, used in several types of modern power reactors. In 1938 he was awarded the Nobel Prize "for his identification of new radioactive elements produced by neutron bombardment and his discovery, made in connection with this work, of nuclear reactions effected by slow nuetrons."

Serving with Dr. Kelly as members of his committee will be: Walter L. Cisler, President of Detroit Edison Company; Dr. Crawford H. Greenewalt, President, E. I. du Pont de Nemours and Company; and Admiral Lewis Strauss, Chairman of the United States Atomic Energy Commission.

Honorary members are the Honorable Clare Boothe Luce, retiring American Ambassador to Italy, and His Excellency Dr. Manlio Brosio, Italian Ambassador to the United States. In addition, an extensive Advisory Sub-Committee will be formed.

Two Laboratories Mathematicians Appointed to Rutgers Faculty

Harold F. Dodge, Quality Results Engineer in the Quality Assurance Department, and Milton E. Terry of the Mathematical Research Department have recently been appointed to the staff of the Rutgers University evening college and graduate programs of applied and mathematical statistics.

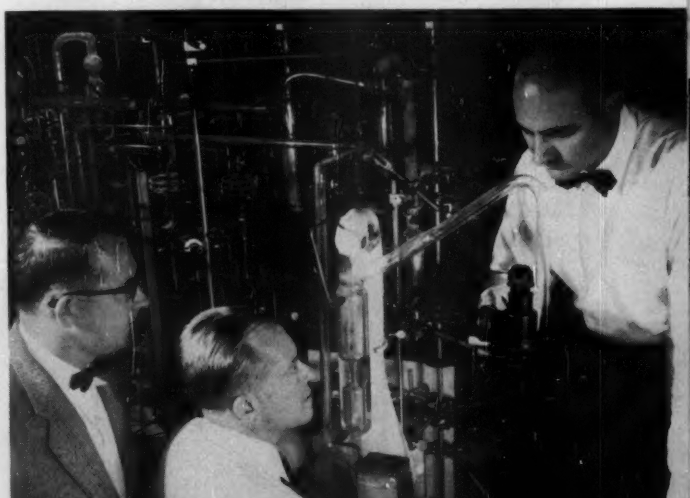
Mr. Dodge will serve as a consultant and adviser in the graduate program in applied and mathematical statistics and Dr. Terry will lecture on design of experiments for the University College and Graduate Faculties.

Internationally known for his development of the concepts and techniques of acceptance sampling plans and the author of many articles and studies in this field, Mr. Dodge is a Fellow of the American Society of Quality Control, the American Statistical Association and the Institute of Mathematical Statistics. He is a former Shewhart Medalist of ASQC and a former Marburg Lecturer for the American Society for Testing Materials.

Dr. Terry joined the Laboratories in 1952, and prior to that was an associate professor of statistics at Virginia Polytechnic Institute. A graduate of Acadia University in 1937, he received his doctorate from the University of North Carolina in 1951. He is Chairman-elect of the Biometrics Section of the American Statistical Association, The Institute of Mathematical Statistics and the American Society of Quality Control.

Hydrogen and Oxygen in Germanium

Germanium is so sensitive to the presence of impurities such as gallium or arsenic that a concentration of one part in ten billion is sufficient to produce a measurable change in its conductivity at room temperature. Since there are about 4.4×10^{22} germanium atoms per cubic centimeter, a concentration of the order of 10^{13} atoms of the impurity per cubic centimeter of germanium is significant.



Left to right: C. D. Thurmond, A. L. Beach and W. G. Guldner with equipment used at Bell Telephone Laboratories for determining the amount of hydrogen and oxygen present in germanium.

The levels of impurity concentration often defy detection by the usual analytical procedures. Poorly identified impurities which cause resistivity changes in germanium as a result of heat treatment have been called "thermium"; poorly identified impurities which cause electron-hole lifetimes to diminish have been called "deathnium". It is significant, therefore, that other impurities present in amounts a hundred thousand times greater produce no known electrical effects. Two of these are hydrogen and oxygen which C. D. Thurmond, W. G. Guldner, and A. L. Beach of Bell Telephone Laboratories have recently found to occur in concentrations greater than 10^{18} atoms per cubic centimeter.

Special samples of germanium were prepared for these studies by hydrogen reduction of pure germanium oxide in purified graphite crucibles. Single crystals were then grown from these samples from graphite crucibles under hydrogen, and one crystal was grown in a vacuum. Tests indicated that all of these crystals were n-type semiconductors with resistivities ranging from 1 to 10 ohm-centimeters. Lifetime of minority carriers was about 100 microseconds.

These crystals, as well as the polycrystalline germanium from which they were grown, were analyzed for hydrogen and oxygen by a refined vacuum fusion technique. The analysis showed no significant variations in hydrogen and oxygen content among the samples prepared under hydrogen, although results on the single crystals were more uniform. In these crystals the hydrogen content was 3 to 4 x 10^{18} atoms per cubic centimeter and the oxygen was between 1 and 2 x 10^{18} atoms per cubic centimeter. For the crystal grown in vacuo, hydrogen was no greater than 1 to 2 x 10^{17} and oxygen about 6 x 10^{16} atoms per cubic centimeter, less by a factor of about fifteen than for those grown in hydrogen.

These results provide conclusive evidence that oxygen and hydrogen are both present in the interior of germanium single crystals. Despite amounts greater than 10^{18} atoms per cc, however, the electronic states of these gases are such that neither holes nor electrons are contributed in adequate numbers to affect the conduction process in germanium. Since about twice as many hydrogen as oxygen atoms are present, it is possible that these two gases react in germanium and exist as water molecules, thus accounting, in part, for their electrical neutrality.

Lee de Forest, inventor of the audion tube, visited with Dr. M. J. Kelly at the Laboratories following the celebration of the fiftieth anniversary of de Forest's invention in New York. Dr. Kelly, who made many important contributions to early electron-tube technology at the Laboratories, holds a new storage tube that provides "memory" in an electronic switching system now being developed.

Contents of the November Bell System Technical Journal

The November, 1956, issue of THE BELL SYSTEM TECHNICAL JOURNAL contains the following articles:

Theory of the Swept Intrinsic Structure by W. T. Read, Jr.

A Medium Power Traveling-Wave for 6,000-Mc Radio Relay by J. P. Laico, H. L. McDowell and C. R. Moster.

Helix Waveguide by S. B. Morgan and J. A. Young.

Wafer-Type Millimeter Wave Rectifiers by W. M. Sharpless.

Frequency Conversion by Means of a Nonlinear Admittance by C. F. Edwards.

Minimization of Boolean Functions by E. J. McCluskey, Jr.

Detection of Group Invariance or Total Symmetry of a Boolean Function by E. J. McCluskey, Jr.

Patents Issued to Members of Bell Telephone Laboratories During October

Bacon, W. M., Knandel, G. J., Krecek, J. A., and Locke, G. A. – *Printing Telegraph Automatic Switching System* – 2,766,318.

Black, H. S., and Clogston, A. M. – *Wave Propagation in Composite Conductors* – 2,769,147.

Black, H. S., and Morgan, S. P., Jr. – *Laminated Conductor* – 2,769,150.

Bond, W. L. – *Uniaxial Crystal Electric Light Valve Compensated for Divergent Light* – 2,768,557.

Buehler, E., and Teal, G. K. – *Process for Producing Semiconductive Crystals of Uniform Resistivity* – 2,768,914.

Clogston, A. M., see Black, H. S.

Clogston, A. M. – *Electrical Conductors* – 2,769,148.

Clogston, A. M. – *Composite Antenna Structure* – 2,169,170.

Cutler, C. C. – *Directive Antenna Systems* – 2,767,396.

Daschke, A. W. – *Compensated Electrical Rectifier and Meter* – 2,767,377.

Early, J. M. – *Semiconductor Signal Translating Devices* – 2,767,358.

Fletcher, R. C. – *Interdigital Filter Circuit* – 2,768,322.

Fritschi, W. W., and Weaver, A. – *Signal Converter for Communication Systems* – 2,765,371.

Graef, R. P. – *Time Delay Switching Apparatus* – 2,765,430.

Hines, M. E. – *Electronic Amplifier* – 2,767,344.

Hogan, C. L. – *Gyromagnetic Resonance Type Microwave Mode Converter* – 2,768,354.

Holden, L. T. – *Fraudulent Ground Corrective for Coin Collector Circuit* – 2,765,366.

Holden, L. T., and Stevens, R. R. – *Telephone Coin Collector* – 2,766,866.

Kelsay, L. W. – *Torpedo-Steering Control System* – 2,766,713.

Kinzer, J. P., Marshall, R. W., and Sproul, P. T. – *Broad Band Testing Circuit* – 2,767,260.

Knandel, G. J., see Bacon, W. M.

Kock, W. E. – *Wave Energy Compound Refractors* – 2,769,171.

Krecek, J. A., see Bacon, W. M.

Kreer, J. G., Jr. – *Spirally Wound Composite Electrical Conductor* – 2,769,149.

Locke, G. A., see Bacon, W. M.

Logan, M. A. – *Calibration Circuit* – 2,765,442.

Lutomirski, K. – *Electronic Tube Alarm Circuit* – 2,768,291.

Maggio, J. B. – *Measurement of Envelope Delay Distortion* – 2,767,373.

Marshall, R. W., see Kinzer, J. P.

Morgan, S. P., Jr., see Black, H. S.

Mumford, W. W. – *Electromagnetic Wave Equalization* – 2,767,379.

Nebel, C. N. – *Transmission Line with Impedance-Matching Terminations* – 2,768,355.

Pierce, J. R. – *High Frequency Electronic Device* – 2,768,328.

Reck, F. – *Means for Stripping Insulated Wire* – 2,765,684.

Retallack, J. B. – *Automatic Message Accounting System* – 2,767,246.

Robertson, G. H., and Walsh, E. J. – *Electron Discharge Devices* – 2,765,421.

Rulison, R. L. – *Surface Treatment of Germanium Circuit Elements* – 2,768,100.

Schiavoni, W. – *Test Trunk Circuit* – 2,767,256.

Slonczewski, T. – *Heterodyne Measuring Circuits* – 2,767,374.

Sproul, P. T., see Kinzer, J. P.

Stevens, R. R., see Holden, L. T.

Teal, G. K., see Buehler, E.

Walsh, E. J., see Robertson, G. H.

Weaver, A., see Fritschi, W. W.

Zobel, O. J. *Impedance Transformer* – 2,767,380.

Papers Published by Members of the Laboratories

Following is a list of the authors, titles, and places of publication of recent papers published by members of the Laboratories:

Allison, H. W., see Moore, G. E.

Anderson, P. W., and Talman, J. D., *Pressure Broadening of Spectral Lines at General Pressures*, Conf. Proc. Breadth of Spectral Lines, pp. 29-61, Oct., 1956.

Arnold, S. M., *The Growth and Properties of Metal Whiskers*, Tech. Proc. Am. Electroplaters Soc., pp. 26-31, 1956.

Bashkow, T. R., *Effect of Nonlinear Collector Capacitance on Collector Current Rise Time*, Trans. I.R.E., PGED, ED-3, pp. 167-172, Oct., 1956.

Beach, A. L., see Thurmond, C. D.

Bridgers, H. E., and Kolb, E. D., *The Distribution Coefficient of Boron in Germanium*, J. Chem. Phys., **25**, pp. 648-650, Oct., 1956.

Buck, T. M., and McKim, F. S., *Depth of Surface Damage Due to Abrasion on Germanium*, J. Electrochem. Soc., **103**, pp. 593-597, Nov., 1956.

Compton, K. G., *Potential Criteria for the Cathodic Protection of Lead Cable Sheath*, Corrosion, **12**, Nov., 1 1956.

Dickinson, D. J., Pollak, H. O., and Wannier, G. H. *On a Class of Polynomials Orthogonal Over a Denumerable Set*, Pacific J. Math., **6**, pp. 239-247, 1956.

Guldner, W. G., *The Application of Vacuum Techniques to Analytical Chemistry,* Vakuum-Technik, pp. 159-166, Oct., 1956.

Guldner, W. G., *Tentative Method for Analysis of Carbon in Nickel,* A.S.T.M., Chem. Anal. Electronic Nickel (E107-56T), pp. 20-25, Sept., 1956.

Guldner, W. G., *Tentative Method of Test for Oxygen. Hydrogen and Nitrogen in Nickel,* A.S.T.M., Chem. Anal. Electronic Nickel (E107-56T), pp. 26-33, Sept., 1256.

Guldner, W. G., see Thurmond, C. D.

Haring, H. E., see Taylor, R. L.

Klemm, G. H., *Automatic Protection Switching for TD-2 Radio System,* Commun. and Electronics, **27**, pp. 520-527, Nov., 1956.

Kolb, E. D., see Bridgers, H. E.

Kompfner, R., *Some Recollections of the Early History of the Traveling Wave Tube,* 1956 Yearbook Phys. Soc. London, pp. 30-33, 1956.

Mallina, R. F., *Solderless Wrapped Connections,* Trans. I.R.E., PGT-1, pp. 12-22, Sept., 1956.

Matthias, B. T., Miller, C. E., and Remeika, J. P., *Ferroelectricity of Glycine Sulfate,* Phys. Rev., **104**, pp. 849-850, Nov. 1, 1956.

McKim, F. S., see Buck, T. M.

Miller, C. E., see Matthias, B. T.

Monforte, F. R., see Van Uitert, L. G.

Moore, G. E., and Allison, H. W., *Emission of Oxide Cathodes Supported on a Ceramic,* J. Appl. Phys., **27**, pp. 1316-1321, Nov., 1956.

Pollak, H. O., see Dickinson, D. J.

Remeika, J. P., see Matthias, B. T.

Rose, D. J., *The Townsend Ionization Coefficient for Hydrogen and Deuterium,* Phys. Rev., **104**, pp. 273-277, Oct. 15, 1956.

Suhl, H., see Walker, L. R.

Swanekamp, F. W., see Van Uitert, L. G.

Taylor, R. L., and Haring, H. E., *Metal-Semiconductor Capacitor,* J. Electrochem. Soc., **103**, Nov., 1956.

Talman, J. D., see Anderson, P. W.

Thurmond, C. D., Guldner, W. G., and Beach, A. L., *Hydrogen and Oxygen in Single-Crystal Germanium as Determined by Vacuum Fusion Gas Analysis,* J. Electrochem. Soc., **103**, pp. 603-605, Nov., 1956.

Torrey, Mary N., *Quality Control in Electronics,* Proc. I.R.E., **44**, pp. 1521-1530, Nov., 1956.

Trumbore, F. A., *Solid Solubilities and Electrical Properties of Tin in Germanium Single Crystals,* J. Electrochem. Soc., **103**, pp. 597-600, Nov., 1956.

Van Uitert, L. G., Swanekamp, F. W., and Monforte, F. R., *Method for Forming Large Ferrite Parts for Microwave Applications,* J. Appl. Phys., Letter to the Editor, **27**, pp. 1385-1386, Nov., 1956.

Walker, L. R., and Suhl, H., *Propagation in Circular Waveguides Field With Gyromagnetic Material,* Trans. I.R.E., AP-4, pp. 492-494, July, 1956.

Wannier, G. H., see Dickinson, D. J.

Wertheim, G. K., *Carrier Lifetime in Indium Antimonide,* Phys. Rev., **104**, pp. 662-664, Nov. 1, 1956.

Talks by Members of the Laboratories

During November, a number of Laboratories people gave talks before professional and educational groups. Following is a list of speakers, titles, and places of presentation.

Acoustical Society of America, Los Angeles, California

Bommel, H. E., *Experimental Techniques in Solid State and Low Temperature Acoustics.*

Burns, F. P., *A Piezo-Resistive Semiconductor Microphone.*

Cook, R. K., *Variation of Elastic Constants and Static Strains With Hydrostatic Pressure; a Method for Calculation from Ultrasonic Measurements.*

Mason, W. P., *Recent Developments in Solid State Acoustics.*

American Physical Society, Chicago, Illinois

Galt, J. K., see Yager, W. A.

Merritt, F. R., see Yager, W. A.

Pearson, G. L., see Wertheim, G. K.

Phillips, J. C., *Singularities in the Density of States.*

Thomas, D. G., *Diffusion and Solubility of Interstitial Zn in ZnO.*

Treuting, R. G., *Torsional Strain and the Screw Dislocation in Whisker Crystals.*

Wertheim, G. K., and Pearson, G. L., *Effect of Dislocations on Lifetime in Germanium.*

Yager, W. A., Galt, J. K., and Merritt, F. R., *Cyclotron Resonance in Graphite.*

Other Talks

Armstrong, J. H., and Wolfe, R. M., *Ferroelectric Devices and Their Applications,* Westchester County Subsection, I.R.E., Norden Laboratories, White Plains, N. Y.

Arnold, S. M., *Metal Whiskers,* Staten Island Institute of Arts and Sciences, Staten Island Museum, St. George, S. I.

Babington, W., *Effect of Process Variables on Quality of Aluminum Alloy Die Casting,* American Society of Die Casting Engineers, Chicago Chapter, Chicago, Ill.

Bavelas, A., *Problem Solving Under Conditions of Restricted Communication, Applied Statistics Seminar,* Princeton University, Princeton, N. J.

Bavelas, A., *Organizational Communication,* Engineer Research and Development Laboratories, Fort Belvoir, Va.

Brown, L. C., *Terrain Avoidance System,* Symp. on Terrain and Obstacle Warning and Avoidance, Cornell Aeronautical Laboratory, Buffalo, N. Y.

Budlong, A. H., *Switching Logic,* Joint Student Branch, A.I.E.E.-I.R.E., Manhattan College, New York City.

Chapin, D. M., *Origin and Development of The Bell Solar Battery,* Center County Subsection A.I.E.E.-I.R.E., Pennsylvania State University, University Park, Pa.

Talks by Members of the Laboratories, Continued

Chapin, D. M., *Solar Energy Conversion*, Bernards Township Junior High School, Basking Ridge, N. J.

Cook, R. K., *Principles of Noise Control in Buildings*, Third West Coast Noise Symp., Los Angeles, Calif.

Dudley, H. W., *Research in Speech Synthesis*, Physics Club of Chicago, Chicago, Ill.

Dudley, H. W., *Human and Electrical Speech Production*, I.R.E., Cedar Rapids, Iowa.

Early, J. M., *The Future*, I.R.E., Garden City, L. I.

Eisinger, J., see Rose, D. J.

Ferrell, E. B., *Basic Concepts of Statistical Analysis*, Oklahoma A. and M., Stillwater, Okla.

Farrell, E. B., *Control Charts for Log-Normal Universes*, Rutgers University, New Brunswick, N. J.

Farrell, E. B., *Control Chaarts for Log-Normal Universes*, Pittsburgh Section, A. S. Q. C., Pittsburgh, Pa.

Fletcher, R. C., *Solid State Device Development at the Bell Telephone Laboratories*, Electrical Engineering Society, Brigham Young University, Provo, Utah.

Garrett, C. G. B., *Recent Work on Germanium Surface at Bell Telephone Laboratories*, Physics Colloquium University of Illinois, Urabana, Ill.

Garrett, C. G. B., *Experiments on Semiconductor Surface Physics*, Physics Colloquium, Purdue, Lafayette, Ind.

Garrett, C. G. B., *Semiconductors and Semiconductor Surface Physics*, Physics Colloquium, Iowa State College, Ames, Iowa.

Hagstrum, H. D., *The Surface Auger Effect*, David Sarnoff Research Center, RCA Laboratories, Princeton, N. J.

Hornbeck, J. A., *Modern Electronics and Its Impact on the Future of Communications*, Kalamazoo (Mich.) College.

Jaycox, E. K., *Spectrochemical Techniques in Research and Control Laboratories*, Meeting of New England Spectroscopic Society, Boston College, Chestnut Hill, Mass.

Joel, A. E., *Digital Information Processing in Telephone Switching Systems*, University of Michigan, Ann Arbor.

Joel, A. E., *Electronics in Telephone Switching Systems*, A.I.E.E.-I.R.E., Detroit, Mich.

Joel, A. E., *Electronic Switching*, A.I.E.E.-I.R.E., Pittsburgh.

Karlin, J. E., *User Preference Research*, Merchandising Committee, New Jersey Bell Telephone Company, Newark.

Keister, W., *Switching Circuits*, Joint Student Branch, A.I.E.E.-I.R.E., Polytechnic Institute of Brooklyn.

Keister, W., *Switching Logic*, Joint Student Branch A.I.E.E.-I.R.E., Newark College of Engineering, Newark, N. J.

Kelly, H. P., *New Measuring Techniques for Color Television*, Graduate Seminar in E.E., Polytechnic Institute of Brooklyn, Brooklyn, N. Y.

Kelly, M. J., *The Science and Technology of Our Nation — Their Contribution and Their Deficiencies*, Century of Commerce Club, Chamber of Commerce of Metropolitan St. Louis, Mo.

Lane, R. F., *Terrain Avoidance Program*, Symp. on Terrain and Obstacle Warning and Avoidance, Cornell Aeronautical Laboratory, Buffalo, N. Y.

Looney, D. H., *Ferrite Devices for Digital Information Storage*, New York Section, I.R.E., Professional Group on Electron Devices, Western Union, New York City.

McMillan, M. B., *Mathematics in Communication*, Rutgers University, New Brunswick, N. J.

Mendizza, A., Salt Spray Test, Educational Sessions, Detroit Branch of American Electroplaters' Society, Detroit, Mich.

Miller, R. A., *Automatic Telephone Answering from an Audio Facilities Point of View*, I.R.E. Professional Group on Audio, Syracuse Chapter, Syracuse, N. Y., and Manufacturing Engineering Group, Western Electric Company, Tonowanda Plant, Buffalo, N. Y.

Miller, R. L., *The Nature of the Vocal Cord Wave*, Meeting of American Speech and Hearing Association, Chicago, Ill.

Moll, J. L., *New Applications of Solid State Materials*, A.I.E.E. Connecticut Section, New Haven, Conn.

Morton, J. A., *Motivation of Scientists Toward Development*, Joint Meeting A.I.E.E.-I.R.E., Engineers Club, Philadelphia, Pa.

Mumford, W. W., *Microwave Noise Figures*, Boston Chapter I.R.E. Professional Group on Microwave Theory and Techniques, Massachusetts Institute of Technology, Cambridge, Mass.

Nielsen, J. W., *Crystal Growth*, University of Kansas, Lawrence, Kan.

Pearson, G. L., *Silicon in Modern Communications*, Physics Colloquium, San Diego State College, San Diego, Calif.

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